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THE HEAVY-OIL ENGINE.

EXTRACT FROM LECTURE ON NAVAL ENGINEERING BY THE ENGINEER-IN-CHIEF U. S. NAVY.

Delivered at the Naval War College, August 3, 1911.

THE HEAVY-OIL ENGINE.

No other type of internal-combustion engine can be considered for large naval installations. Gasoline and kerosene engines have no prospect of development in sufficiently large units, and the stowage of their fuel is too dangerous to be considered. Bituminous producers require purifying apparatus of such size and weight that they are no longer attractive. Anthracite producers have been developed with some degree of success, but this fuel is not sufficiently available for naval use.

The Diesel engine had its beginnings in 1893, and today is manufactured for stationary purposes all over Europe and to a less extent in America. Its development for marine purposes during the last few years has been rapid, and there is

promise that in comparatively few years we will be propelling battleships with it.

The operation of the Diesel engine is as follows: there is no gasifier, carbureter, or ignition device. Consider the cycle as beginning at the end of the stroke with the cylinder filled with air. When the piston makes the return stroke, the air is compressed to about 500 pounds, the work done in compressing it heating it to a temperature above the burning point of the fuel. As the next forward stroke is beginning the fuel is sprayed in under pressure of about 600 pounds. The heat in the air ignites it and it burns during the forward stroke, exerting a pressure on the piston never much greater than that required for compressing the air. The development of pressure in a Diesel engine is comparatively slow, the fuel being burned rather than exploded as in other types of internal-combustion engine.

The work of compressing the air and the forward impulse are thus done in two strokes. If means are provided for sweeping out the products of combustion by a current of pure air the whole cycle of operation is performed in two strokes, and we have a *two-cycle* engine. If, however, two more strokes are required, one to sweep out the products of combustion and another to draw in pure air, we have four strokes to complete the operation and a *four-cycle* engine. The four-cycle type is very heavy, but is preferred for stationary purposes on account of its simplicity. On account of its lighter weight and the greater facility with which it can be reversed the two-cycle type is preferred for marine purposes. In both types the cylinder walls, heads and pistons are water-cooled.

Licensees under the Diesel patents have worked independently in each country of Europe and in America with some exchange of improvements. The most marked success has been obtained by firms in Germany, Switzerland, Italy and Belgium.

Several European nations have for some time been using a heavy-oil engine of the four-cycle Diesel type for submarines. All of them appear at this time to be installing a somewhat

lighter engine of the two-cycle type. In our Navy, in the latest submarines the Electric Boat Company is installing a two-cycle engine for which that company has the American rights from the German designers. The Lake Company is installing the Sulzer engine, to be built in Switzerland. A St. Louis company has acquired the American rights to this engine, and there is hope that it will in a short time be built in this country.

A considerable number of ocean-going vessels are being equipped with Diesel engines of various makes, up to nearly 2,000 horsepower. Some of these are in service, but it is too early at this time to give exact figures as to economy and durability.

We are projecting an engine of this type of about 1,800 horsepower, to be used in the submarine tender authorized by the last Congress.

With a view to their use in very large high-powered vessels the leading European builders of Diesel engines are experimenting with engines developing upwards of 1,000 H.P. per cylinder. One of these has built a single-cylinder engine developing 1,200 brake horsepower which has been inspected by officers of our service. It has been tried, but we have not yet been put in possession of the trial data. Another similar engine, with a single cylinder, to develop 2,000 horsepower, is building, but has not yet been tested. A third engine, to develop 6,000 horsepower in three cylinders, of the double-acting, two-cycle type, has been built, and is being tested. This engine is for the German Navy, and the details of construction as well as the trial data have not been made public. In all these large engines the diameter of cylinders is from 32 inches to 40 inches, the stroke is about 40 inches, and the revolutions per minute not greater than 150.

The dimensions are thus moderate, and well suited to propeller efficiency.

Thus, the heavy-oil engine has been developed to a degree that renders it worthy of consideration for marine installations. Hitherto it has not merited such consideration, on account of the limited power that could be developed in a single

cylinder. An installation of any size required a multiplicity of cylinders. With the possibility of obtaining from 1,000 to 2,000 H.P. in a cylinder of moderate dimensions, the extensive adoption of this type of engine for naval purposes may be close at hand.

Experience with smaller engines of the Diesel two-cycle type indicates that they will be readily reversible, and will have a satisfactory speed control.

The economy of the Diesel engine is twice that of the steam engine. Its weight and the space required for its installation will not be considerably less, but it permits the elimination of the boiler and condenser, which have always been the most troublesome elements of our machinery installations.

Some difficulty is anticipated in the development of the large Diesel engine in connection with the high pressures and temperatures that are to be handled. Its durability and reliability in marine installations remain to be demonstrated. However, the inherent advantages of the engine will tend to force its development in the face of considerable difficulties.

DESCRIPTION AND TRIALS OF U. S. TORPEDO-BOAT DESTROYERS *WARRINGTON* AND *MAYRANT*.

By W. B. Robins, Associate.

Torpedo-boat destroyers numbers 30 and 31, the *Lewis Warrington* and *John Mayrant*, provided for by Act of Congress approved May 13, 1908, belong to the first group of oil-burning destroyers of our Navy and contain the first installation of Zoelly turbines for naval propulsion in this country.

The contract for these vessels, signed October 1, 1908, called for delivery within 24 months, the contractors being The William Cramp & Sons Ship and Engine Building Company, Philadelphia, Penna. The *Warrington* was delivered in March, 1911, and the *Mayrant* in July, 1911, both at the Navy Yard, Philadelphia. The *Warrington* was launched June 18, 1910, and the *Mayrant* April 23, 1910.

The general requirements of the contract were as follows:

Displacement, about 742 tons.

Speed on four-hour full-speed trial, 30 knots.

Trials.—(*a*) A progressive trial over a measured-mile course for standardizing the screws, about twenty runs to be made over the course.

(*b*) A full-speed (30 knots) four-hour trial, air pressure not to exceed an average of 5 inches of water, steam pressure at high-pressure turbine not to exceed 240 pounds above atmosphere.

(*c*) A twelve-hour trial at 25 knots.

(*d*) A twenty-four hour trial at 16 knots. (The requirements for the duration of trials (*c*) and (*d*) were reduced to ten hours.)

The contract price for each vessel was $664,000.00, of which $389,000.00 was allotted for machinery.

GENERAL DESCRIPTION OF THE VESSEL.

HULL.

As the hull arrangement of the vessels of the class has been fully described and illustrated in previous numbers of the JOURNAL, it is only necessary to repeat the principal dimensions, etc.

Hull Data.

Length between perpendiculars, feet and inches	289–00
over all, feet and inches	293–10½
on load water line, feet and inches	289–00
of straight keel, feet and inches	241–09⅞
Breadth, molded, extreme, feet and inches	26–04½
extreme, over plating, feet and inches	26–05½
over guards, feet and inches	27–00
Depth, molded, main deck at side, M.S. No. 82½, feet and inches	16–04¾
Draught above bottom of keel, feet and inches	8–04
Ratio of length to beam at L.W.L.	11.0622
Displacement, normal, 8 ft. 4 ins. draught, tons	742.
per inch at 8 ft. 4 ins. draught, tons	12.02
Number of frames, spaced 21 inches throughout	166.
compartments below main deck	36.

Heights Above 8 Feet 4 Inches, W. L.

Foremast, feet and inches	60–1
Mainmast, feet and inches	60–4⅛
Bridge at center, frame 37, top of beam, feet and inches	23–9$\frac{7}{16}$
side, frame 37, top of beam, feet and inches	23–2¾
Top of forecastle deck at stem, feet and inches	17–0⅝
Main deck at stern, feet and inches	8–0⅛
Height of bridge at center above forecastle deck, feet and inches	7–6

Capacities of Fresh-Water Tanks.

Compartment:	Gallons.	Tons F.W.
A–6	3,315	12.31
Gravity tank	50	0.19
Total	3,365	12.50

Capacities of Reserve-Feed Tanks.

Compartment:	Gallons.	Tons F.W.	Tons S.W.
C–2	4,006	14.88	15.30

Capacities of Trimming Tanks.

Compartment:	Gallons.	Tons F.W.	Tons S.W.
A–1, forward	515	1.91	1.97
A–2, forward	2,746	10.20	10.49
D–7, aft	2,044	7.59	7.81
D–8, aft	1,408	5.23	5.38

SMALL BOATS.

2 20-foot whale boats.
1 20-foot 10-inch power dory.
1 17-foot dory.

COMPLEMENT.

Commanding officer	1
Wardroom officers	3
Seamen's branch	27
Engine-room branch	51
Special branch	2
Commissary branch	2
Messmen's branch	2
Total	89

MAIN TURBINES.

There are two Zoelly compound impulse turbines arranged on two shafts, each having a backing turbine in the after end. The turbines were designed to develop about 13,000 total shaft horsepower at 650 r.p.m. with steam at 250 pounds gage pressure at the boilers. Each turbine is composed of two essential parts: the fixed part or casing and the moving part or rotor. In the casing are mounted the fixed diaphragm plates and expanding guide blades and also the intermediate guide blades, and on the rotor are mounted the discs and drum carrying the moving blades. The rotor is supported at each end by a bearing connected to the casing.

Turbine Cylinders.

The ahead and astern cylinders are of cast iron divided horizontally through the center line and connected by a cast-iron exhaust belt, which is also divided horizontally along the center line, so that the upper halves of the ahead and astern cylinders and exhaust belt can be lifted as one piece for the purpose of inspection or repair. The main exhaust pipe leading to the condenser is connected to the top of the exhaust belt. The diaphragm plates separating the pressure stages are of steel plate riveted to forged-steel hubs and rims. The part of the diaphragm (called the guide-blade ring) containing the expanding guide blades is of cast iron divided horizontally along the center line and fitting into a groove in the casing and having a projection around its inner circumference which fits into a groove on the rim of the diaphragm. The guide-blade ring has a tight fit in the casing, and each half is secured by two screws, half in the casing and half in the guide-blade ring, so that when the upper half casing is lifted the upper half guide-blade ring will come away with it, and when the rotor is lifted the lower half guide-blade ring will remain in the casing. The inner circumference of each diaphragm hub is fitted with brass rings forming a system of labyrinth packing to prevent steam leaking through from stage to stage around the rotor shaft. The passages between the expanding guide blades, in the diaphragms, constitute and perform the functions of parallel-sided nozzles in which the steam expands, reducing its pressure and increasing its velocity. The expanding guide blades are of sheet steel, one-sixteenth of an inch thick, held in place by being fitted in the mould when the guide-blade rings are cast.

Rotors.

The rotors, at the high-pressure and astern ends consist of steel-plate discs riveted to forged-steel hubs and rims, the latter having grooves for the blading. At the low-pressure ends of the ahead and astern parts of each rotor cast-steel

spiders are fixed to the rotor shaft and connected with each other by a forged-steel drum on which are mounted the blades for the low-pressure stages. The rotor shafts are of forged steel with axial holes their full length. The rotor wheels have a light driving fit on the shaft and are secured from turning by feather keys, the shaft diameter being stepped to allow the rotor wheels to be put on successively, and they are further secured by a steel nut on the shaft.

Blades.

The rotor blades and the intermediate guide-blades in the casings are of drawn brass. The blades are fitted into T-shaped grooves in the casings, rotor discs and drums, and are kept at proper distance by brass pieces between the blades. The tips of the blades are connected by drawn-brass shrouding of modified channel section. The tip clearance is five sixty-fourths (.078125) of an inch, and the longitudinal clearance about $^{3}/_{16}$ of an inch.

Speed Regulation.

There are three principal running speeds: "slow speed," "medium speed" and "full speed," which are obtained by admitting steam to the turbines as follows:

Throttles open.

"Slow speed"	3½ inch to 1st stage.		
"Medium speed"	3½-inch to 1st stage.	6-inch to 4th stage.	
"Full speed"	3½-inch to 1st stage.	6-inch to 4th stage.	7½-inch to 6th stage.

Turbine Glands.

The turbine glands are steam packed and are formed of carbon rings held in place by cast-iron rings and steel springs.

U. S. S. *MAYRANT*, TURBINE DATA.—AHEAD.

Stage.		1	2	3	4	5	6	7	8	9	10	11	12	Drum. 13	Drum. 14	Drum. 15	Drum. 16
Pitch, diameter, inches		59 1/16	59 1/16	59 1/16	59 1/16	59 1/16	59 1/16	59 1/16	59 1/16	59 1/16	59 1/16	59 1/16	59 1/16	59 1/16	59 1/16	59 1/16	59 1/16
Number of nozzle openings		18	23	37	107	51	107	120	120	120	120	120	120	120	...	...	...
Radial height of nozzle mouth, ins.		19/64	19/64	19/64	5/8	1 5/32	33/64	11/32	7/16	37/64	49/64	1	1 5/16	1 1/2	...	...	...
Number of rows of moving buckets		2	2	2	2	2	2	2	2	2	2	2	2	6	4	4	6
Number of rows stationary buckets		1	1	1	1	1	1	1	1	1	1	1	1	5	4	4	6
Height of buckets, ins.	1st row	11/16	11/16	11/16	49/64	55/64	1 3/32	47/64	53/64	1 1/32	1 5/16	1 41/64	2 5/64	2 1/2	6 9/64	7 9/16	9 1/16
	2d row	23/32	23/32	23/32	25/32	59/64	1 17/64	51/64	63/64	1 3/16	1 1/2	1 15/16	2 23/64	3 15/64	6 9/64	7 9/16	9 1/16
	3d row	23/32	23/32	23/32	25/32	59/64	1 17/64	51/64	63/64	1 3/16	1 1/2	1 15/16	2 23/64	3 1/2	6 9/64	7 9/16	9 1/16
	4th row	...	...	...	...	...	...	..	...	...	...	...	...	3 15/64	6 9/64	7 9/16	9 1/16
	5th row	...	...	...	...	...	...	...	...	...	...	...	...	3 15/64	6 9/64	7 9/16	9 1/16
	6th row	...	...	...	...	...	...	...	...	...	...	...	...	3 15/64	6 9/64	7 9/16	9 1/16
	7th row	...	...	...	...	...	...	...	...	...	...	...	...	3 15/64	6 9/64	7 9/16	9 1/16
	8th row	...	...	...	...	...	...	...	...	...	...	...	...	3 15/64	6 9/64	7 9/16	9 1/16
	9th row	...	...	...	...	...	...	...	...	...	...	...	...	3 15/64	...	...	9 1/16
	10th row	...	...	...	...	...	...	...	...	...	...	...	...	3 15/64	...	...	9 1/16
	11th row	...	...	...	...	...	...	...	...	...	...	...	...	3 15/64	...	...	9 1/16
	12th row	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	9 1/16
Number buckets per row.	1st row	471	471	471	471	471	471	471	471	471	471	471	471	471	326	334	334
	2d row	80	100	155	470	210	470	470	470	470	470	470	470	470	471	471	471
	3d row	471	471	471	471	471	471	471	471	471	471	471	471	471	326	334	334
	4th row	...	...	...	...	...	...	...	...	...	...	...	...	326	471	471	471
	5th row	...	...	...	...	...	...	...	...	...	...	...	...	471	326	334	338
	6th row	...	...	...	...	...	...	...	...	...	...	...	...	326	471	471	471
	7th row	...	...	...	...	...	...	...	...	..	...	...	...	471	326	334	338
	8th row	...	...	...	...	...	...	...	...	...	...	...	...	326	471	471	471
	9th row	...	...	...	...	...	...	...	...	...	...	...	...	471	...	...	338
	10th row	...	...	...	...	...	...	...	...	...	...	...	...	326	...	...	471
	11th row	...	...	...	...	...	...	...	...	...	...	...	...	471	...	...	338
	12th row	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	471

U. S. S. *MAVRANT*, TURBINE DATA.—ASTERN.

Drum. Stage.	Pitch, diameter, inches.	Number of nozzle openings.	Radial height of nozzle mouth, inches.	Number of rows of moving buckets.	Number of rows of stationary buckets.	Height of buckets, inches. First row.	Second row.	Third row.	Fourth row.	Fifth row.	Sixth row.	Seventh row.	Number of buckets per row. First row.	Second row.	Third row.	Fourth row.	Fifth row.	Sixth row.	Seventh row.
1	55⅛	92	1 9/16	2	1	1 1/16	1 1/16	1 1/16	...	...	...	...	439	438	439	...	...	...	...
2	55⅛	112	1 5/16	2	1	1 5/16	1 5/16	1 5/16	...	...	...	...	439	438	439	...	...	...	...
3	55⅛	112	1 5/16	4	1	1 5/16	1 5/16	1 5/16	2 1/16	2 1/16	2 1/16	2 1/16	439	438	439	304	439	304	439
4	55⅛	...	...	2	3	4 5/16	4 5/16	4 5/16	4 5/16	...	...	...	304	439	304	439	...	...	...
5	55⅛	...	...	2	2	5 1/16	5 1/16	5 1/16	5 1/16	...	...	...	312	439	312	439	...	...	...
6	55⅛	...	...	2	2	5 11/16	5 11/16	5 11/16	5 11/16	...	...	...	312	439	316	439	...	...	...
7	55⅛	...	...	2	2	6 5/16	6 5/16	6 5/16	6 5/16	...	...	...	316	439	...	...	...	...	...

Turbine Drains.

At the lowest point of each turbine casing, near the exhaust end, there is a 2-inch drain leading through a check valve to the main air-pump suction.

Turbine Relief Valves.

At the inlet end of each ahead and astern turbine there is a 2-inch spring-loaded relief valve, set at 250 pounds pressure.

SHAFTING.

Each system of shafting comprises the rotor spindle, two sections of line shaft, one stern-tube shaft and one propeller shaft. All the shafting is hollow. The thrust collars are on the after ends of the rotor spindles. The couplings at the forward ends of the stern-tube shafts are of the removable-disc and split-collar type to allow the shafts to be withdrawn outboard, and the propeller and stern-tube shafts are joined by tapered sleeve couplings with feathers and cotters. All other shaft couplings are of the usual flange and bolt type.

Data of Line Shafting, etc.

Line Shafts:	
Number, each side	2
Diameter, inches	07¼
of hole, inches	04
Length, forward section, feet and inches	12–01⅞
after section, feet and inches	14–07
Diameter of coupling flanges, inches	13¼
Thickness of coupling flanges, inches	01¼
Number of coupling bolts	8
Mean diameter of coupling bolts, inches	01⅝
Stern-tube shaft:	
Diameter, inches	07½
of hole, inches	04
Length, feet and inches	26–00
Thickness of brass sleeves at bearings, inches	00$\frac{7}{16}$
Propeller shaft:	
Diameter, inches	07½
of hole, inches	04
Length, feet and inches	29–02¼
Diameter of threaded end for propeller nut, inches	05½
Thickness of brass sleeves at bearings, inches	00$\frac{7}{16}$
Total length of shafting, including rotor, each side, feet and inches	101–11¾

BEARINGS.

Each line of shafting has one steady bearing, two stern-tube bearings and two strut bearings. The steady bearings and their caps are of cast iron, babbitt lined, fitted with oil guards and oil-baffle rings. The stern-tube and strut bearings are of the usual naval type, of composition lined with lignumvitæ.

Data of Bearings.

Steady bearings:	
Number, each side	1
Diameter, inches	07¼
Length, inches	11¾
Stern-tube bearings:	
Diameter, inches	08⅜
Length, forward bearing, inches	39
after bearing, inches	39
Strut bearings:	
Diameter, inches	08⅜
Length, forward bearings, inches	24
after bearing, inches	39

PROPELLERS.

The propellers are of the three-bladed, true-screw type, and are solid manganese-bronze castings, the faces of the blades being machined to the designed pitch.

Propeller Data.

Number of blades, each	3
Diameter, feet and inches	6–08
Pitch, feet and inches	6–02
Projected area, square feet	20.41
Helicoidal area, square feet	23.20
Disc area, square feet	34.90
Ratio, pitch to diameter	0.926 : 1
projected area to disc area	0.585 : 1
Thickness of blade at root, inches	04
Width of key (two for each propeller), inches	01⅛
Depth of key, inch	00¾
Depth of lower tip of blade below keel, inches	03⅛
Immersion of upper tip of blade at 8 ft. 4 ins. draught, inches	23⅛

MAIN CONDENSERS.

There are two main condensers of oval, flat-sided section with the long axis vertical, located outboard alongside the turbines. The shells are of steel plate, stiffened by angles and stay rods. The heads are of sheet copper with brass flanges. The tube sheets are of rolled naval brass and the tubes of composition: copper, 70; tin, 1; zinc, 29. The tubes are packed at both ends with cotton-tape packing and screwed ferrules and are supported at two intermediate points by steel-plate diaphragms with brass ferrules.

Data of One Condenser.

Length between tube sheets, feet and inches	15–00
Height of shell, inside, feet and inches	7–08¾
Breadth of shell, inside, feet and inches	2–08
Thickness of shell plates, inch	00¼
tube sheets, inch	01
Number of tubes	2,038
Outside diameter of tubes, inch	00⅝
Thickness of tubes, B.W.G., number	18
Cooling surface, square feet	5,002
Diameter of circulating water inlet, inches	15
outlet, inches	15
Length of rectangular exhaust-steam inlet, feet and inches	7–07
Breadth of rectangular exhaust steam inlet, feet and inches	2–09
Diameter of forward air-pump suction nozzle, inches	07
after air-pump suction nozzle, inches	06½

MAIN AIR PUMPS.

There are two main air pumps of the Blake twin vertical-beam type, located at the after end of the engine room, close to the center line of the ship.

Data of One Main Air Pump.

Diameter of steam cylinders, inches	12
pump cylinders, inches	26
Stroke of pistons, inches	18
Diameter of suction nozzle, inches	09½
discharge nozzle, inches	08
steam pipe, inches	02
exhaust pipe, inches	02½

MAIN CIRCULATING PUMPS.

There are two single-inlet centrifugal circulating pumps driven by vertical single-cylinder enclosed steam engines. They are located at the outboard sides of the engine room, forward of the condensers. The engines are enclosed in oil-tight casings, and forced lubrication is furnished by pumps driven from the crankshafts, connections also being provided from the forced-lubrication system of the main turbines.

Data of One Main Circulating Pump.

Diameter of impeller, inches	26
Width of impeller at tip of blades, inches	03½
Diameter of suction nozzle, inches	15½
discharge nozzle, inches	15
steam cylinder, inches	07
Stroke of steam piston, inches	06
Diameter of steam pipe, inches	01½
exhaust pipe, inches	02

BOILERS.

There are four White-Forster water-tube oil-burning boilers arranged in two firerooms, with three smoke pipes, one each for the forward and after boilers and one for the two midship boilers. The middle smoke pipe has a division plate throughout its length which prevents either of the two boilers opening into it being influenced by the draft or combustion conditions existing in the other boiler. Each boiler has one cylindrical steam drum and two semi-cylindrical water drums. The steam drum is made of two plates, the one forming the lower half, into which the tubes are expanded, being thicker than the one forming the upper half. The upper plates or tube sheets of the water drums also are made thicker than the lower plates.

The steam drum contains two 12-inch × 16-inch manholes in the front head to which also are attached the feed valves, water gages, and try cocks. The main steam, safety and sur-

face-blow valves are located on top of the steam drum. The steam valve is 6½-inch diameter and the safety valve is a 4-inch triplex.

The lower water chambers to which the tubes are fixed are large enough to admit of easy access, a 12-inch × 16-inch manhole being fitted in each drum.

The tubes all have a slight curvature, the radius of which is the same for all the tubes, and is so designed that any tube can be withdrawn through one or the other of the two manholes in the front head of the steam drum. This feature of all tubes having the same curvature simplifies the quantity of spares required and also facilitates cleaning the tubes inside, as all can be cleaned by a brush with handle curved to the radius of the tubes. Plate I shows the boiler with casings removed, giving a view of the arrangement of tubes and drums. Plate II shows the casings in place.

The steam and water drums are connected at their back ends by two large downcomer pipes.

The feed water enters the boiler a little below the water line and discharges above the water line through a B. & W. reducing feed nozzle with inverted spray pan; zinc plates of Navy standard size with steel-plate basket for catching pieces of disintegrated metal are fitted in both upper and lower drums and each of the lower drums is fitted with a 1¼-inch blow-off valve.

Large doors are fitted at the front end of the boiler so that the whole length of tubes is exposed for cleaning, and a brush can be passed between the tubes from end to end of the boiler.

The casings are of galvanized steel plate insulated with asbestos millboard and magnesia. Each boiler has eleven Schutte & Koerting oil burners with air registers of the Babcock & Wilcox Co. type. The flow of the products of combustion is directly across the tubes to the uptake openings, baffles being fitted under the uptake openings to cause all the gases to flow in a direction perpendicular to the tubes.

The bottom of the combustion chamber is lined with a layer of 12-inch × 12-inch × 2-inch tile, over which is placed

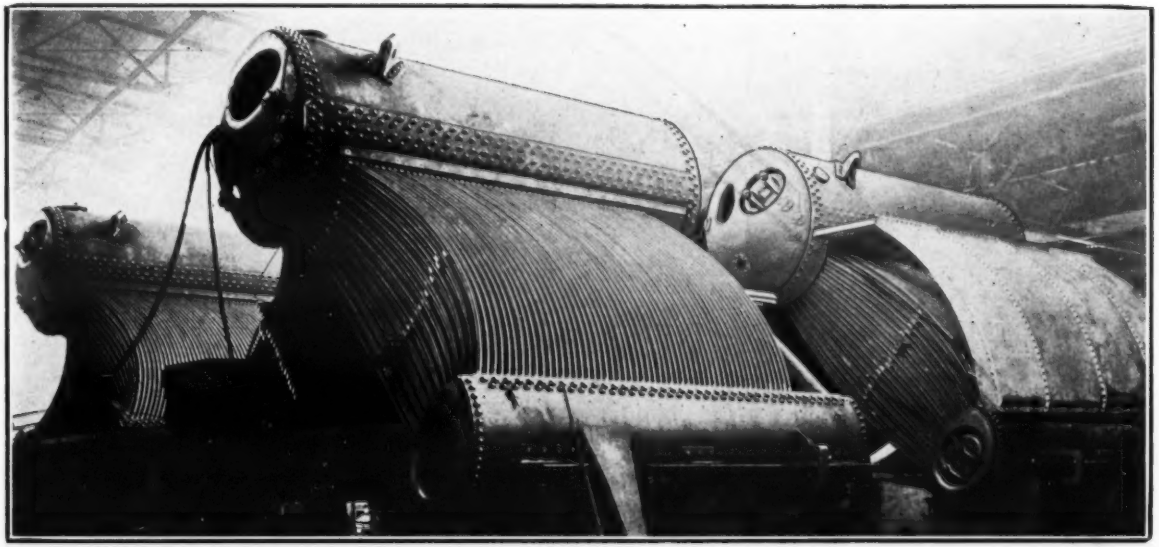


Plate I.

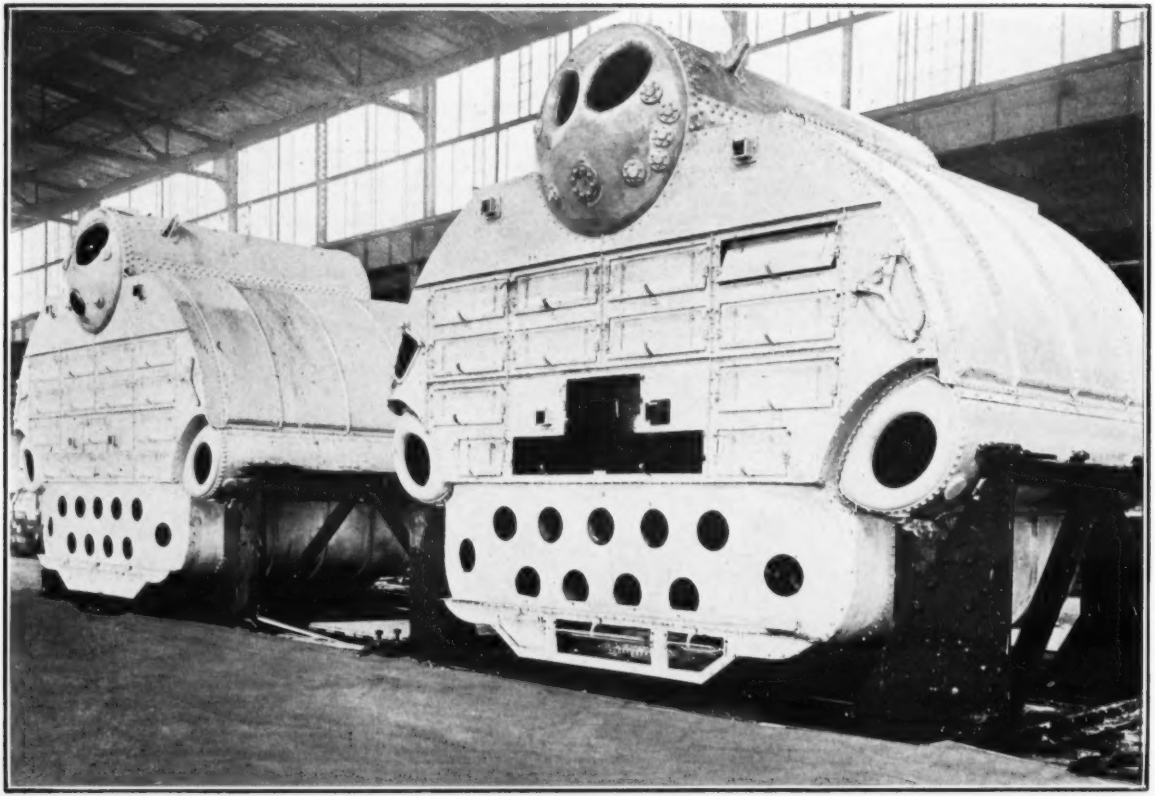


Plate II.

Plate II.

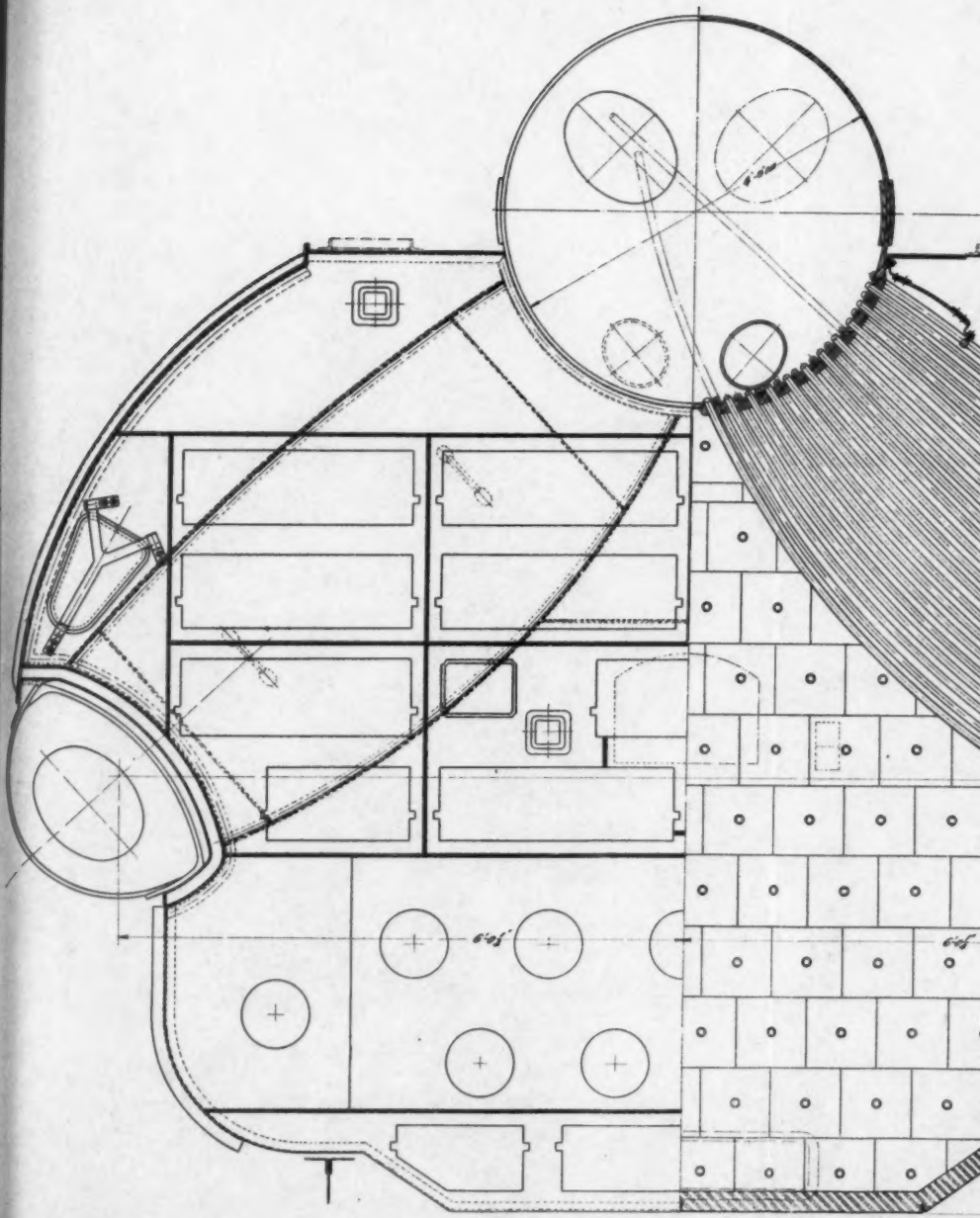
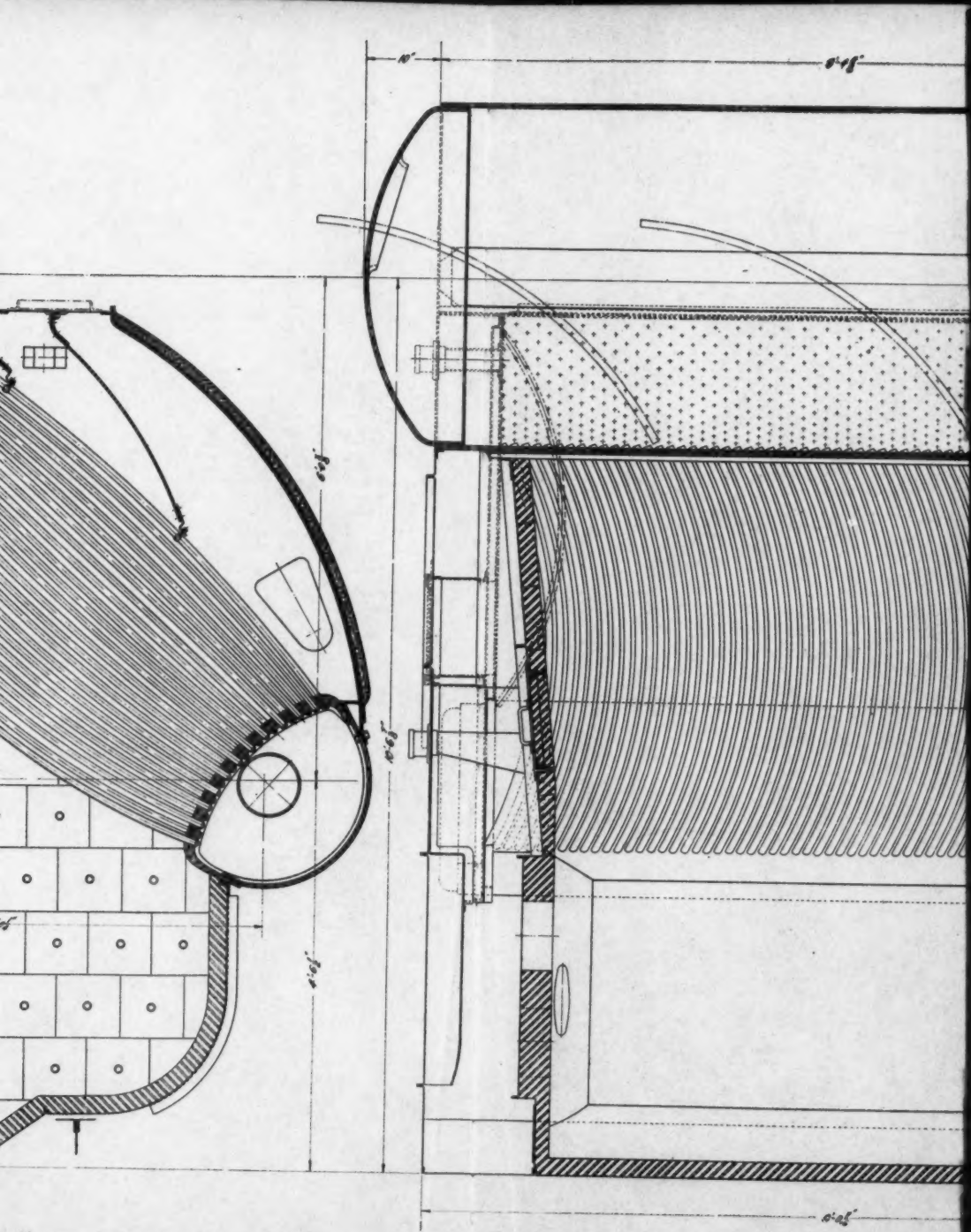


Plate III.—WHITE-



E-FORSTER BOILER, U. S. S. "WARRINGTON" AND "MAVRANT."

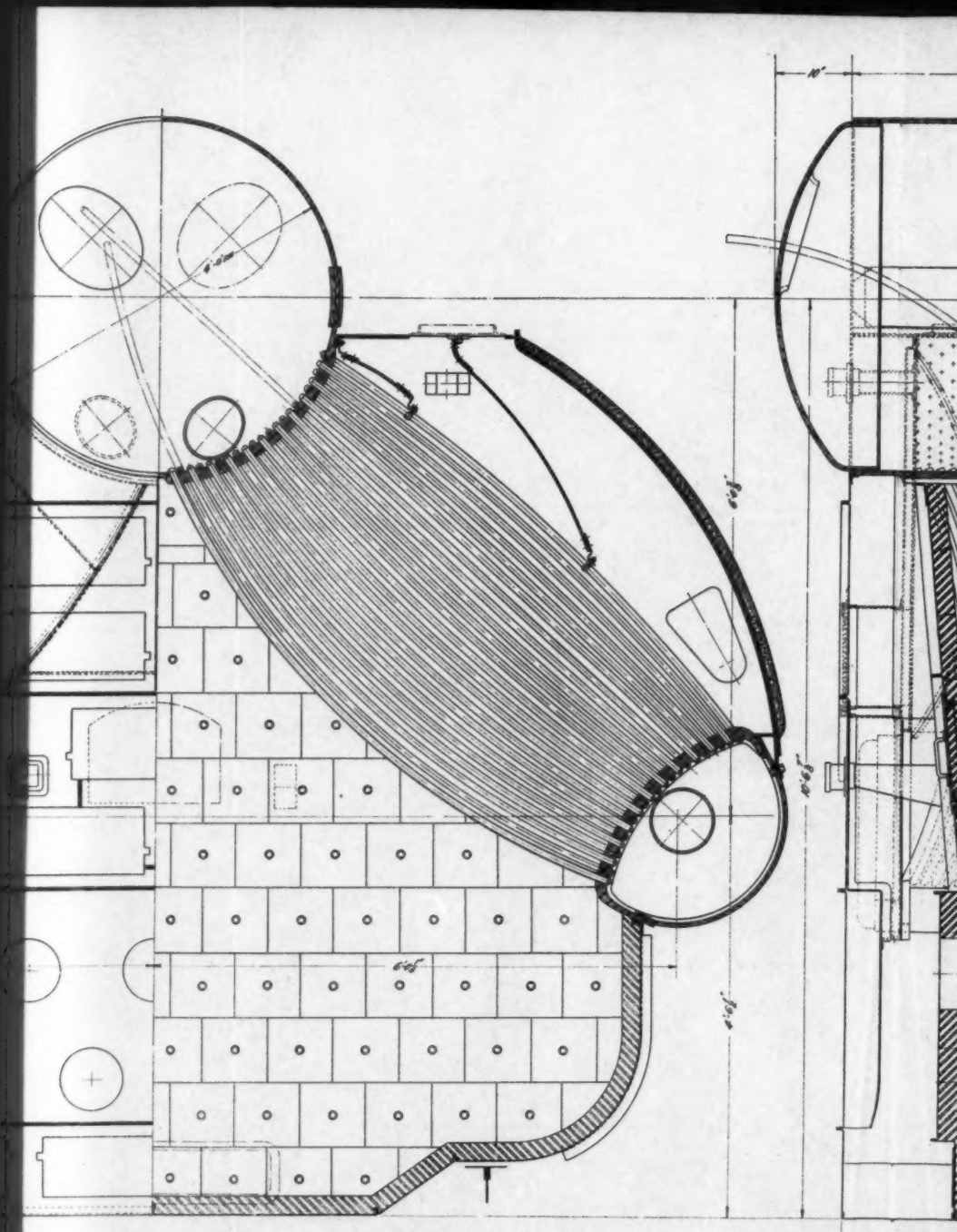
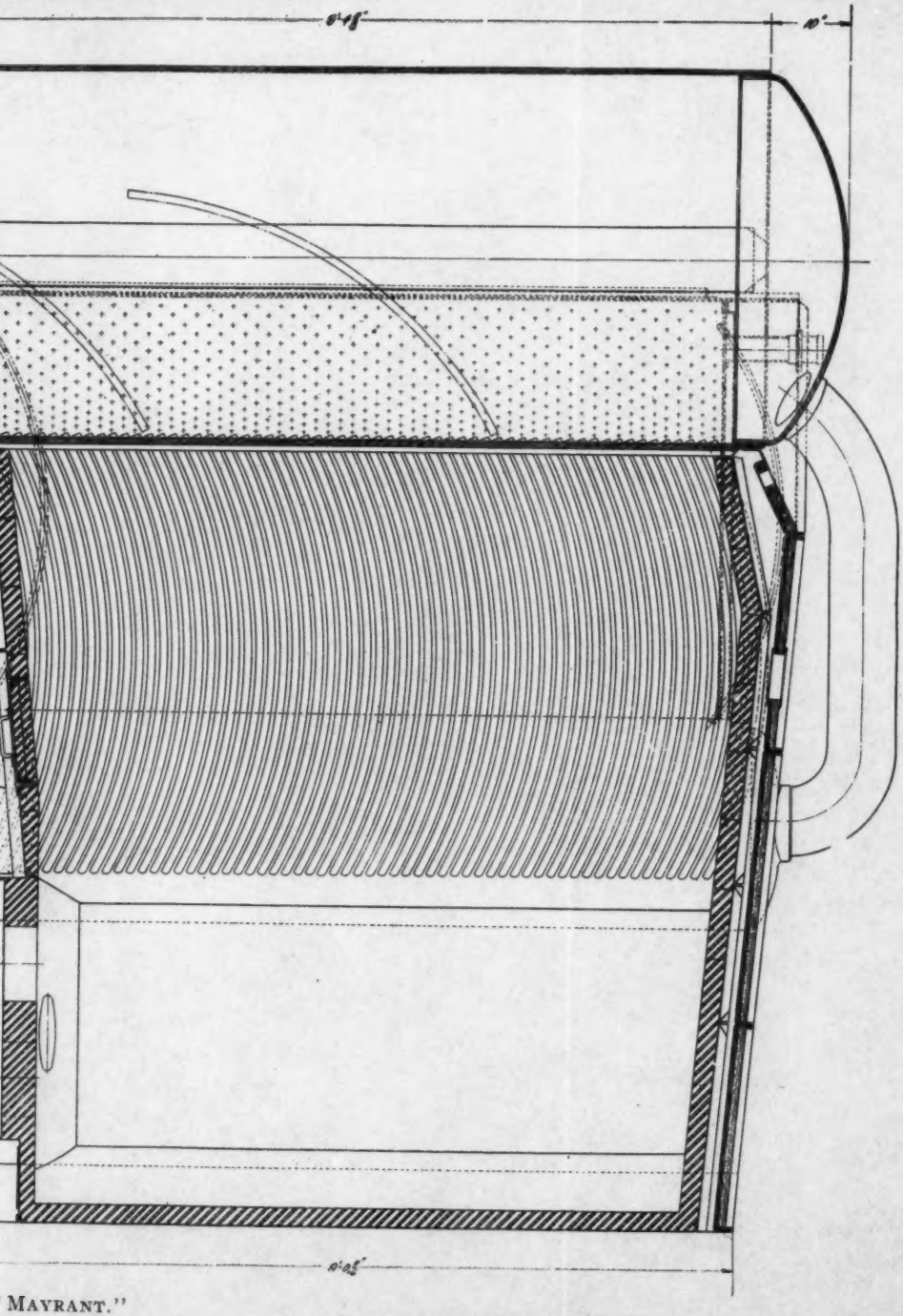


Plate III.—WHITE-FORSTER BOILER, U. S. S. "WARRINGTON" AND "M



MAYRANT."

a layer of fire brick laid in a mixture of fire clay and cement, provision being made for expansion. The back of the furnace is protected by fire brick and asbestos, outside of which is asbestos millboard ¼ inch thick, a 2-inch air space, and 1 inch of magnesia, the whole being backed by steel plate. The same construction is employed at the front, except that there is an air space or chamber about 12 inches wide, to admit air to oil burners. The sides of the boiler, from the water drum to the uptake, are protected by ¼-inch millboard, and 1-inch magnesia, enclosed by 14 U. S. S. G. plate.

Data for One Boiler.

Length of steam drum, feet and inches	11.00⅝
Inside diameter of steam drum, inches	48
Thickness of steam drum, tube sheet, inches	01 9/16
top plate, inch	00 9/16
heads, inch	00⅝
Radius of curvature of steam drum heads, inches	36
water drum (semi-cylindrical), inches	15
Thickness of water-drum tube sheet, inches	01 9/16
bottom plate, inch	00 7/16
heads, inch	01
Radius of curvature of water-drum heads, inches	19½
Number of tubes (seamless, cold-drawn steel)	2,728
Outside diameter of tubes, inch	01
Thickness of tubes, B.W.G., number	12
Length of longest tube, feet and inches	7–04¾
shortest tube, feet and inches	6–05
Radius of curvature of tubes, feet and inches	7–01½
Number of downcomer pipes	2
Diameter of downcomer pipes, inside, inches	08⅛
Thickness of downcomer pipes, inch	00⅜
Heating surface, one boiler, square feet	4,500
Total heating surface, four boilers, square feet	18,000
Combustion space, one boiler, cubic feet	394.74
Ratio of combustion space to heating surface	1:11.4
Area of smoke pipe, square feet	13.32
Ratio of combustion space to smoke-pipe area	29.64:1
Number of oil burners, one boiler	11
External length of boiler, feet and inches	11–08 1/16
width of boiler, feet and inches	14–07⅜
height of boiler, feet and inches	12–07 7/16
Designed working pressure, pounds per square inch	250

Weight of one boiler complete, dry, pounds	45,740
tons	20.42
with water at steaming level and temperature, pounds	54,370
with water at steaming level and temperature, tons	24.27

Each boiler is provided with the following fittings:

1 3-inch to 1¾-inch reducing-feed elbow (internal).

1 2½-inch combined main and auxiliary-feed stop and check valve.

1 6½-inch dry pipe.

1 6½-inch steam stop valve.

1 1¼-inch internal surface-blow pipe with scum pan.

1 1¼-inch surface-blow valve.

2 1¼-inch bottom-blow valves.

8 12-inch by 6-inch by ½-inch zincs (4 in steam drum, 4 in water drums).

1 4-inch triple spring-loaded safety valve.

2 Klinger reflex water gages.

3 try cocks.

2 1-inch drain cocks.

1 steam gage, 6½-inch dial.

2 12-inch by 16-inch manholes in steam drum.

1 12-inch by 16-inch manhole in each water drum.

Connections are provided for blowing soot from the boiler tubes either by steam or compressed air.

UPTAKES AND SMOKE PIPES.

The uptakes are made of three thicknesses of plate with an air space of 1½ inches between the inner and middle courses and one inch of magnesia between the middle and outer courses. The smoke pipes are of flat-sided oval section with the long axis fore and aft. They are raked aft 7½ inches, the rake beginning about 6 inches above the deck.

Smoke-Pipe Data.

	Forward and Aft.	Amidships.
Long diameter, inside, feet and inches	4–06⅜	7–06⅜
Short diameter, inside, feet and inches	3–06⅜	3–11⅞
Long diameter, outside, feet and inches	5–00	8–00½
Short diameter, outside, feet and inches	4–00	4–06
Height above base line, feet and inches	37–06	37–06
oil burners, mean, feet and inches	33–02	33–02
Area of cross section, inside, square feet	13.32	26.63
Ratio of combustion space to smoke-pipe area	29.64:1	29.65:1

MAIN STEAM PIPING.

All main steam piping is of seamless-drawn steel rolled into wrought-steel flanges. There is a 6½-inch branch leading from the stop valve on each boiler. The branches from the two forward boilers unite in one 9-inch pipe running aft along the starboard side to the engine-room bulkhead and the branches from the two after boilers unite in one 9-inch pipe running aft along the port side to the engine-room bulkhead.

Main Exhaust Pipes.

The main exhaust pipes from the turbines to the condensers are rectangular trunks, built up of steel plates and shapes.

Length of exhaust opening in turbine, feet and inches	5-1½
Breadth of exhaust opening in turbine, feet and inches	4-11
Area of exhaust opening in turbine, square inches	3,628

AUXILIARY STEAM PIPING.

The auxiliary steam piping consists of a line of pipe through both firerooms and around the engine room, with a cross connection in the after fireroom and branches to the various auxiliaries. Steam is supplied through stop valves, one on each boiler, located below the seats of the main steam stop valves.

Auxiliary Exhaust Piping.

The exhaust pipe branches from the various auxiliaries lead into an auxiliary exhaust main running through the firerooms and continuing in a loop around the engine room. In the

engine room there are connections for directing the auxiliary exhaust into the main condensers and the auxiliary condenser. The dynamo turbine exhaust has connections for by-passing it direct to the starboard main condenser. In the after fireroom the auxiliary exhaust has connections to the feed-water heater and the escape pipe.

MAIN AIR-PUMP SUCTION AND DISCHARGE.

From each main condenser there are two air-pump suction pipes, a 7-inch dry suction from the forward end and a 6½-inch wet suction from the after end. The wet and dry suctions from each condenser unite in a special fitting, located close to the air pump, and having a division plate along the horizontal center line. The dry suction enters above the division plate and the wet suction below, and both are led through a 9½-inch gate valve into the air pump. There is a 5-inch cross connection between the wet-suction pipes from the two condensers. The discharge pipes from the two main air pumps unite in one pipe leading to the main feed tank. This pipe was fitted with temporary connection to the feed-measuring tank on deck for use during the trials.

FEED PIPING.

There is a feed-suction pipe from the main feed tank at the after end of the engine room, leading through the engine room and both firerooms. This pipe has a connection from the reserve feed tank at the forward end of the engine room and suction branches to the main and auxiliary feed pumps. One of the main feed pumps has a suction from the cross-connection pipe of the main air-pump wet suctions and a 1-inch make-up feed connection from the reserve feed tank. The discharges from the main feed pumps unite in a pipe leading to the firerooms through a grease extractor and feed-water heater, with connections for by-passing either the heater or grease extractor or both. Each auxiliary feed pump discharges to the boilers in its compartment.

FEED-WATER HEATER.

In the after fireroom, and projecting through the engine-room bulkhead about two feet into the engine room, there is a cylindrical feed-water heater. The feed water passes through the tubes and the exhaust steam is admitted to the shell around the tubes. The shell and tube sheets are of steel plate, the heads of cast steel and the tubes of brass. The tubes are expanded into the tube sheets and expansion is provided for by flanged rings joining the two parts of the shell at the engine-room bulkhead. The drain from the feed-heater shell has connections to port main condenser, auxiliary condenser and feed tank.

Data of Feed Water Heater.

Diameter of shell, inside, inches	21
Thickness of shell, inch	00 5/16
Length between tube sheets, feet and inches	7–00
Diameter of tubes, outside, inch	00 5/8
Thickness of tubes, B.W.G., number	18
Number of tubes	436
Thickness of tube sheets, inches	01 1/8
Diameter of feed-water inlet and outlet, inches	05
exhaust-steam inlet, inches	07
drain outlet, inches	03
Heating surface, square feet	499.38

FEED PUMPS.

There are two main feed pumps at the forward end of the engine room on the port side, and one auxiliary feed pump in each fireroom. They are of the Blake vertical simplex piston type.

Feed Pump Data.

	Main.	Auxiliary.
Diameter steam cylinder, inches	14 1/2	14 1/2
pump cylinder, inches	10	10
Stroke of pistons, inches	12	12
Diameter of suction nozzle, inches	05 1/2	04 1/2
discharge nozzle, inches	04 1/2	03 1/2
steam pipe, inches	02	02
exhaust pipe, inches	02 1/2	02 1/2

FEED AND FILTER TANK.

There is a galvanized sheet-steel feed tank of 724 gallons capacity in the after end of the engine room, the upper part being fitted as a filter, with two filter compartments through which the water flows in series.

FEED-MEASURING APPARATUS.

During the trials the discharge from the main air pumps was led to a calibrated measuring tank on deck, from which it was discharged by gravity to the feed tank in the engine room. The measuring tank was made with two compartments of 3,009 pounds capacity each, and the discharge pipe from the air pumps was fitted with a swivel connection allowing the flow to be directed alternately into the measuring compartments, each compartment having a discharge at the bottom.

FIRE AND BILGE PUMPS.

At the after end of the engine room on the starboard side there is a Blake vertical simplex-piston fire and bilge pump. This pump has connections to draw from the sea and the engine-room bilge and to discharge to the sea, the firemain and the distiller circulating system.

In each fireroom there is a Blake vertical simplex-piston fire and bilge pump, with connections to draw from the sea and the fireroom bilges and to discharge to the sea and the firemain.

There is a 3½-inch by 4-inch by 4-inch vertical simplex bilge pump situated on the berth deck forward, for pumping out the bilges of the forward compartments.

	Engine room.	Fireroom.
Diameter of steam cylinder, inches	10	08
pump cylinder, inches	07	05
Stroke of pistons, inches	08	12
Diameter of suction nozzle, inches	04	03½
discharge nozzle, inches	03½	03
steam pipe, inches	01¼	01
exhaust pipe, inches	01½	01½

AUXILIARY CONDENSER AND PUMP.

At the after end of the engine room, on the port side, there is a horizontal cylindrical auxiliary condenser, having 256 square feet of cooling surface. The air and circulating pump is of the Blake horizontal combined type, located under the condenser. The circulating pump draws from the auxiliary injection valve and discharges overboard through the condenser. There is a connection on the circulating-pump discharge leading to the circulating system of the oil cooler. The air pump draws from the condenser and discharges to the main air-pump discharge pipe to the feed tank.

Auxiliary Air and Circulating-Pump Data.

Diameter of steam cylinder, inches	06
circulating-pump cylinder, inches	08
air-pump cylinder, inches	08
Stroke of pistons, inches	07
Diameter of circulating-pump suction, inches	04
discharge, inches	04
air-pump suction, inches	04
discharge, inches	03
steam pipe, inch	01
exhaust pipe, inches	01¼

TURNING GEAR.

At the after end of each turbine there is a worm wheel, on the main shaft, engaging with a removable worm, turning being accomplished by means of a rachet wrench applied to the worm shaft.

FORCED-DRAFT BLOWERS.

The forced draft is of the closed-fireroom type, there being two Sturtevant blowers in each fireroom, driven by direct-connected Terry steam turbines. The shafts of the blowers are vertical, the blowers being close up under the deck with the turbines below them. Lubrication is accomplished by a pump driven from the turbine shaft, oil passages and tubes being fitted to the various journals.

Blower Data.

Diameter of fan, inches	39
Width at tip of vane, inches	07⅞
Number of vanes	8
Rated capacity of turbine, cubic feet of air per minute at pressure of 5 inches of water	23,000
brake horsepower of turbine	63
steam consumption, pounds per B.H.P. per hour	60

LUBRICATING SYSTEM.

Oil for the turbine bearings, thrust and steady bearings is supplied by a forced-lubrication system working under a pressure of about 20 pounds per square inch. There are two 4½-inch by 5-inch by 6-inch Blake vertical simplex steam pumps which pump the oil from a 160-gallon drain tank through a cooler to the various bearings. The oil from the bearings returns by gravity to the drain tank, which is situated low down in the after end of the engine room. Glass-covered light boxes, containing electric lights, are fitted on the return pipes at all the bearings so that the flow of oil can be observed. Thermometers are fitted in the oil pipes to and from the cooler and in the drain pipe at each bearing. From the forward end of the oil-supply pipe to the turbines there is a connection to each circulating-pump engine with an independent drain from the circulating-pump engines to the drain tank.

There is a 4½-inch by 5-inch by 6-inch Blake horizontal simplex steam pump for circulating water through the oil cooler. This pump draws from the auxiliary injection valve and discharges overboard through the cooler. There is an emergency connection from the auxiliary circulating pump to the oil-cooler circulating system.

The cooler is cylindrical in shape and has a sheet-copper shell and brass tubes, tube sheets and heads. The tubes are fitted with screwed ferrules at the tube sheets. The oil flows through the tubes and the circulating water through the shell around the tubes. By means of baffles in the shell and heads both oil and water are made to travel the length of the shell four times.

Oil Cooler Data.

Diameter of shell, inside, inches	18⅜
Thickness of shell, B.W.G., number	9
Length between tube sheets, feet and inches	3–06½
Thickness of tube sheets, inch	00⅞
Number of tubes	260
Diameter of tubes, outside, inch	00⅝
Thickness of tubes, B.W.G., number	18
Cooling surface, square feet	150.67

There is a galvanized-steel oil-stowage tank in the engine room, divided into two compartments, one of 112 gallons and the other of 80 gallons capacity, for turbine and auxiliary lubricating oil respectively. There is also a 44-gallon lamp-oil tank in the engine room. Pipes are provided for filling the tanks from deck, and there is a pipe from the bottom of the turbine oil compartment to the oil-drain tank for the purpose of supplying oil to, or making up leakage of the forced-lubrication system.

HOISTING GEAR.

A system of trolleys and chain hoists is installed for lifting and moving aside the turbine cylinders and rotors and also for the main condenser heads.

REVOLUTION-COUNTER GEAR.

There is a continuous rotary-motion revolution counter for each shaft, the two counters being combined in one rectangular case at the working platform. The counters register one for every ten revolutions of the turbines, the unit revolutions being read from graduations on the first numbered wheel of each counter. Below the counter case there is a combined dial revolution indicator for the two shafts. The counters are driven by shafting, with bevel gears and universal joints, from worms on the forward ends of the turbine shafts. In addition to the counters there is provided for each turbine a tachometer with 8-inch dial situated alongside the throttle valves.

EVAPORATING AND DISTILLING PLANT.

There are two evaporators and two distillers, the rated capacity of the plant being 2,000 gallons of fresh water per 24 hours. The evaporators are in the engine room at the after end, and the distillers are above the main deck on the starboard side of the deck house immediately abaft the engine room. The evaporator shells are vertical cylinders, built up of steel plates and angles. The steam coil of each evaporator consists of forty seamless-drawn brass tubes, bent U shape, and a brass steam head with steel-plate cover.

Data for One Evaporator.

Diameter of shell, inside, feet and inches	2–05
Length of shell, inside, feet and inches	4–11⅜
Thickness of shell, inch	00 $\frac{3}{16}$
Number of tubes	40
Diameter of tubes, outside, inches	01½
Thickness of tubes, B.W.G., number	13
Heating surface, square feet	75.25
Designed working pressure, shell, pounds per square inch	30
coil, pounds per square inch	250

The distillers are cylindrical in shape and are placed in a vertical position. The shells are seamless-drawn brass tubing, and the tubes, tube sheets and heads are of brass. The tubes are expanded into both tube sheets, and expansion in the direction of their length is provided for by a stuffing box and gland formed by the top head and tube sheet.

Data of One Distiller.

Diameter of shell, outside, inches	09
Length of shell, feet and inches	2–05¼
Thickness of shell, inch	00 $\frac{7}{64}$
Number of tubes	43
Diameter of tubes, outside, inch	00⅝
Thickness of tubes, B.W.G., number	18
tube sheets, inch	00½
Cooling surface, square feet	17

There is a 3½-inch by 4-inch by 4-inch simplex evaporator-feed pump and a distiller fresh-water pump of the same size. The distiller circulating water is supplied by the engine-room fire and bilge pump.

OIL-FUEL SYSTEM.

The Schutte and Koerting system of oil burning, described in detail in the February, 1911, number of the JOURNAL, is used on these vessels, with independent air registers of the Babcock & Wilcox Co. type.

In each fireroom there is a 6-inch by 7-inch by 12-inch vertical simplex oil-supply pump to which are connected manifolds, valves and piping, enabling it to draw from any one of the stowage or settling tanks and to discharge to any one of the stowage or settling tanks, or overboard.

There are two 4½-inch by 3-inch by 4-inch vertical duplex oil-service pumps in each fireroom, which take the oil from the settling tanks and discharge it to the burners through two Schutte and Koerting film heaters.

Deck fittings are provided, connected to the oil-stowage piping, for taking oil from a barge or wharf. The ends of the suction pipes in the tanks are surrounded by steam coils to facilitate the flow of oil. For starting up, in case there is no steam available, there is installed in each fireroom a hand pump and starting heater, the latter fitted with a grate for burning coal or other suitable fuel. The hand pump draws from the settling tanks and discharges through the starting heater to the burners.

For clearing the settling tanks of water there is a handy-billy pump at the after end of the forward fireroom with a suction from the bottom of each settling tank and a discharge overboard.

FUEL-OIL MEASURING APPARATUS.

On the trials of the *Warrington* the oil consumption was measured by taking levels, before and after the trials, in the tanks from which oil was used, capacity curves having been prepared for the tanks.

On the *Mayrant* the oil consumption during trials was measured by passing the oil, on its way from the supply pump to the settling tank, through a pair of calibrated measuring tanks on deck. These tanks were of about 20½ cubic feet ca-

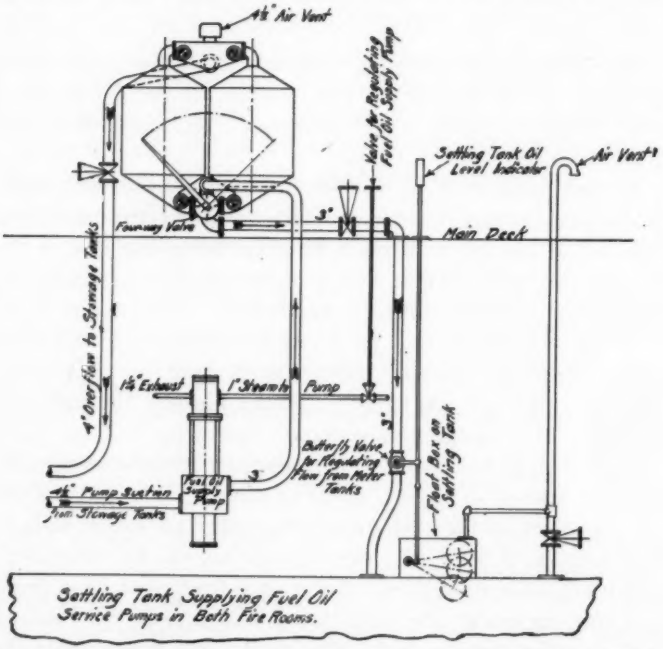

4½" Air Vent
Valve for Regulating Fuel Oil Supply Pump
Settling Tank Oil Level Indicator
Air Vent
3"
Fourway Valve
Main Deck
4" Overflow to Storage Tanks
1¼" Exhaust
1" Steam
Pump
Butterfly Valve for Regulating Flow from Meter Tanks
Float Box on Settling Tank
4½" Pump Suction from Storage Tanks
Fuel Oil Supply Pump
Settling Tank Supplying Fuel Oil Service Pumps in Both Fire Rooms.

Plate IV.—DIAGRAMMATICAL ARRANGEMENT OF FUEL-OIL MEASURING APPARATUS.

pacity each, and a four-way valve operated by a hand lever was fitted in the supply and discharge connections to the tanks, allowing them to be alternately filled and emptied. A diagrammatic view of the arrangement used is shown on Plate IV.

AIR-COMPRESSOR PLANT FOR TORPEDOES.

In the forward end of the engine room there is a vertical steam-driven four-stage air compressor for supplying compressed air to the torpedo tubes. The rated capacity of the

compressor is 20 cubic feet per hour at a pressure of 2,500 pounds per square inch. There is an air main running through the engine and firerooms with connections for driving pneumatic tools, blowing soot off the boiler tubes, and running the fuel-oil service pumps. This main is supplied by a branch from the air-compressor discharge through a reducing valve which reduces the pressure to 100 pounds.

ANCHOR GEAR AND STEERING GEAR.

The anchor gear and steering gear are of the same character and arrangement as installed on the other vessels of this class, descriptions of which have already appeared in the JOURNAL.

ELECTRIC GENERATORS.

At the forward end of the engine room there are two 5-kilowatt 125-volt General Electric Company dynamos, driven by Curtis steam turbines.

TORSION METERS.

The torsion meters used on these vessels are of the contractors' own make, from designs of Mr. J. F. Metten, Chief Engineer of the Cramp Company. In arrangement and principle of operation they are the same as those used on the *Smith* and *Lamson*, described in the August, 1910, number of the JOURNAL, but some improvements have been made in details relating to adjustment and taking up wear. A dust-tight sheet-iron case has also been added, enclosing the working parts.

BUILDERS' TRIALS.

Warrington.

Dock trials of the machinery of the *Warrington* were run on November 22, 23 and 28, 1910. The main and auxiliary machinery was operated under various conditions, special attention being given to the oil-burning system.

Builders' sea trials were conducted in the vicinity of Delaware Breakwater December 7, 8 and 9, 1910. The main engines and auxiliaries worked satisfactorily, but considerable trouble was experienced from fluttering of the burning oil, causing vibration of the boiler casings and smoke pipes when attempting to run at contract speed. After returning to the contractors' works, some changes were made in the tips and air registers of the oil burners. Further trials were conducted by the contractors on January 7, 9 and 10, 1911, over the measured-mile course near Delaware Breakwater and out to sea in that vicinity. The performance of the machinery was very satisfactory, the contract speed being attained and exceeded without undue forcing, and no further trouble being experienced with the oil burners.

Mayrant.

Dock trials of the machinery of the *Mayrant* were run on February 20 and 27, 1911, all parts working satisfactorily. On March 2, 1911, the *Mayrant* had a sea trial in the vicinity of Delaware Breakwater, during which the contract speed was attained without difficulty.

On March 8, 1911, the *Mayrant* left the builders' yard for Delaware Breakwater with the expectation of beginning the official trials the following day, but an injury to the starboard propeller necessitated the return of the vessel the same day.

On May 12, 1911, the *Mayrant* left the builders' yard for Delaware Breakwater, and between that date and May 16th the machinery was tested by the builders under various conditions with satisfactory results.

STANDARDIZATION TRIALS.

The standardization trials of both vessels were run over the Delaware Breakwater course, the *Warrington* on January 11, 1911, and the *Mayrant* on May 16, 1911. Curves plotted with the data obtained on these trials are given on Plates V and VI.

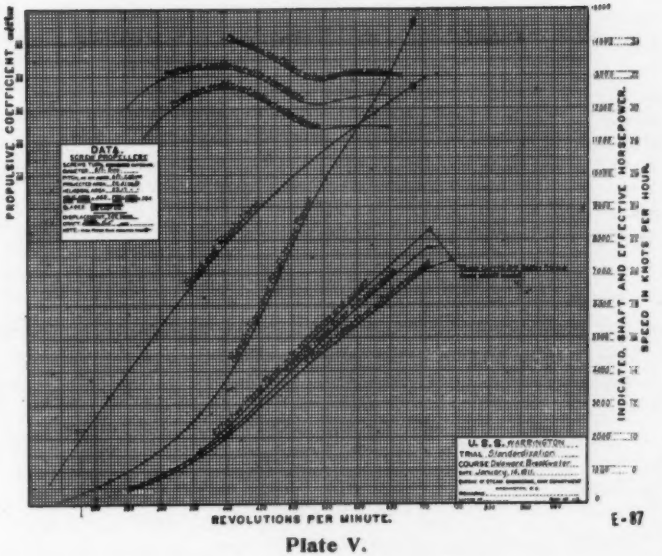


Plate V.

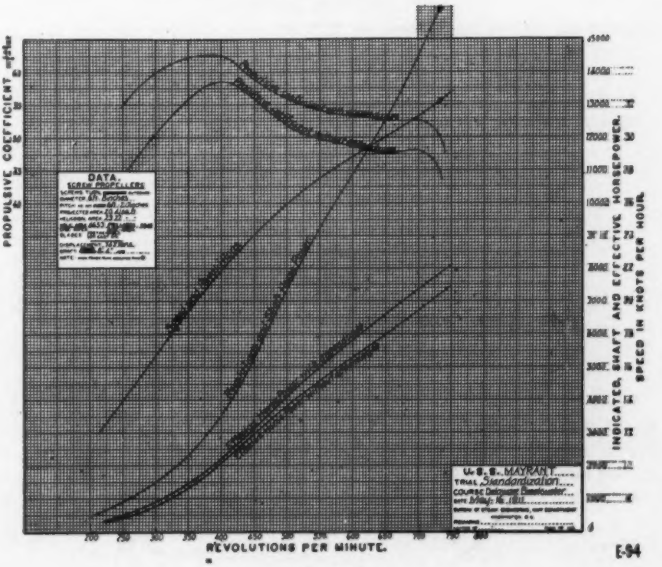


Plate VI.

FOUR-HOUR FULL-SPEED TRIALS.

	Warrington.	*Mayrant.*
Date	January 12, 1911.	May 17, 1911.
Course	Off Delaware Capes.	Off Delaware Capes.
Weather	Cloudy, occasional rain.	Overcast, cloudy, hazy.
Wind	Light airs to gentle breezes from S.W.	Light northeasterly airs to gentle breezes from N.N.E.
Sea	Moderate.	Smooth.
Average displacement, tons	729.2	733.6

PERFORMANCE, FOUR HOURS, FULL-SPEED TRIALS.

	Warrington.	*Mayrant.*
Pressures:		
Average steam pressure at boilers, gage, pounds	246.0	246.0
Average pressure in lubricating-oil system, gage, pounds	21.1	15.0
pressure fuel oil to burners, boiler A, gage, pounds	194.3	210.0
B, gage, pounds	198.1	210.0
C, gage, pounds	198.8	207.0
D, gage, pounds	198.8	207.0
Vacuum in condenser, starboard, ins. of mercury	29.0	28.2
port, inches of mercury	28.9	28.7
Revolutions, or double strokes, per minute:		
Shaft No. 1, starboard	641.03	659.39
2, port	641.41	659.38
Average	641.22	659.38
Pumps, main air, starboard	46.0	49.7
port	46.0	43.4
circulating, starboard	351.0	399.0
port	358.0	392.8
feed, inboard	35.5	29.4
outboard	34.7	28.9
lubricating-oil, inboard	33.9	24.6
outboard	33.9	31.2
oil-cooler circulating	45.0	50.6
fire and bilge, engine room	24.0	47.4
fuel-oil service, forward fireroom	42.3	53.8
after fireroom	54.5	44.0
Forced-draft blowers (average of four)	1,211.8	1,307.0
Speed of ship, knots	30.123	30.219
Slip of propeller, in per cent. of its own speed, based on mean pitch:		
Shaft No. 1, starboard	22.87	24.87
2, port	22.91	24.87
Mean	22.89	24.87

	Warrington.	*Mayrant.*
Air pressure in firerooms, inches of water	4.85	4.80
Shaft horsepower :		
Shaft No. 1, starboard	6,468.0	6,550.0
2, port	6,378.0	6,590.0
Total	12,846.0	13,140.0
Indicated horsepower :		
Total auxiliaries in operation	487.0	...
Temperatures :		
Injection, starboard, degrees F	45.5	...
port, degrees F	...	54.1
Discharge, starboard, degrees F	70.6	86.6
port, degrees F	79.5	86.2
Feed to heater, degrees F	53.0	85.2
from heater, degrees F	139.6	153.0
Main steam, degrees F	395.6	405.0
Engine-room air, degrees F	72.7	89.5
Outside air, degrees F	49.3	59.0
Fireroom air, degrees F	82.0	86.4
Fuel oil to burners, boiler A, degrees F	167.0	143.8
B, degrees F	160.0	143.8
C, degrees F	183.0	138.2
D, degrees F	175.0	138.2
Smokepipe gases, degrees F	808.0	645.0
Fuel oil :		
Specific gravity	0.899	...
Deduced data :		
Square feet of heating surface per S.H.P.	1.401	1.370
Cooling surface (main condensers), square feet per S.H.P.	0.7787	0.7613
During above trials the following auxiliaries were in operation :		
Main air pumps	2	2
circulating pumps	2	2
feed pumps	2	2
Forced-lubrication pumps	2	2
Oil-cooler circulating pump	1	1
Fire and bilge pump (engine room)	1	...
(fireroom)	1	...
(sanitary)	1	1
Oil-fuel pumps	2	2
Oil-tank pump	1	1
Feed heater	1	1
Dynamo	1	1
Forced-draft blowers	4	4
Steering engine, as required	1	1
Steam to galley	used	used
heating system	used	not used
Boilers A, B, C and D	4	4

During above trials the following auxiliaries were in operation:	*Warrington.*	*Mayrant.*
Burners, boiler A	9	10
B	9	10
C	9	10
D	10	9

TEN-HOUR TRIALS AT TWENTY-FIVE KNOTS.

	*Warrington.**	*Mayrant.*
Date	January 15, 1911.	May 18, 1911.
Course	Off Delaware Capes.	Off Delaware Capes.
Weather	Cloudy and foggy.	Hazy.
Wind	Light S. by W. to fresh N.N.W.	Light variable airs to light breezes from S.S.W.
Sea	Moderate.	Smooth.
Average displacement, tons	735	725.6

PERFORMANCE, TEN HOURS, TWENTY-FIVE-KNOT TRIALS.

Pressures:	*Warrington.*	*Mayrant.*
Average steam pressure at boilers, gage, pounds	246.0	245.3
pressure in lubricating-oil system, gage, pounds	20.4	13.4
pressure fuel oil to burners, boiler A, gage, pounds	200.0	169.2
B, gage, pounds	204.0	169.2
C, gage, pounds	200.0	184.1
D, gage, pounds	200.0	184.1
Vacuum in condenser, starboard, ins. of mercury	29.0	28.2
port, inches of mercury	29.0	28.5
Revolutions, or double strokes, per minute:		
Shaft No. 1, starboard	502.77	487.90
2, port	502.08	487.90
Average	502.43	487.90
Pumps, main air, starboard	29.4	32.2
port	30.6	31.2
circulating, starboard	346.0	350.8
port	342.0	324.2
feed, inboard	...	...
outboard	38.3	37.8
lubricating-oil, inboard	27.6	39.8
outboard	24.4	...
oil-cooler circulating	44.0	40.0
fire and bilge, engine room	24.0	...
after fireroom	50.0	43.8
fuel-oil-service, forward fireroom	34.4	33.8
after fireroom	53.0	29.0
Forced-draft blowers (average of two)	1,136.0	1,189.0

* The *Warrington* slowed down for thick fog after running 7 hours and 50 minutes. Duration of 7 hours for this trial allowed by Navy Department.

	Warrington.	*Mayrant.*
Speed of ship, knots	25.926	25.439
Slip of propeller, in per cent. of its own speed, based on mean pitch :		
Shaft No. 1, starboard	15.36	14.54
2, port	15.24	14.54
Mean	15.30	14.54
Air pressure in firerooms, inches of water	3.2	2.7
Shaft horsepower :		
Shaft No. 1, starboard	3,926.0	3,323.0
2, port	3,877.0	3,517.0
Total	7,803.0	6,840.0
Indicated horsepower :		
Total auxiliaries in operation	278.0	...
Temperatures :		
Injection, starboard, degrees F	53.1	56.6
port, degrees F	48.4	...
Discharge, starboard, degrees F	69.9	81.7
port, degrees F	71.0	83.2
Feed to heater, degrees F	68.3	70.7
from heater, degrees F	135.3	131.8
Main steam, degrees F	396.7	405.0
Engine-room air, degrees F	84.4	90.0
Outside air, degrees F	50.0	62.8
Fireroom air, degrees F	88.6	99.1
Fuel oil to burners, boiler A, degrees F	153.6	131.1
B, degrees F	147.1	131.1
C, degrees F	185.7	146.0
D, degrees F	172.1	146.0
Smokepipe gases, degrees F	704.0	498.0
Fuel oil :		
Specific gravity	0.899	...
Deduced data ;		
Square feet of heating surface per S.H.P.	2.307	2.632
Cooling surface (main condensers) square feet per S.H.P.	1.282	...
During above trials the following auxiliaries were in operation :		
Main air pumps	2	2
circulating pumps	2	2
feed pump	1	1
Forced-lubrication pumps	2	1
Oil-cooler circulating pump	1	1
Fire and bilge pump (engine room)	1	...
(sanitary)	1	1
Oil-fuel pumps	2	2
Oil-tank pump	1	1
Feed heater	1	1

During above trials the following auxiliaries were in operation:	*Warrington.*	*Mayrant.*
Dynamo	1	1
Forced-draft blowers	2	2
Steering engine, as required	1	1
Steam to galley	used	used
heating system	used	not used
Boilers A, B, C and D	4	4
Burners, boiler A	6	5 to 7
B	6	6 to 8
C	6	6 to 7
D	6	6 to 7

TEN-HOUR TRIALS AT SIXTEEN KNOTS.

	Warrington.	*Mayrant.*
Date	January 16, 1911.	May 19, 1911.
Course	Off Delaware Capes.	Off Delaware Capes.
Weather	Clear.	Cloudy, hazy and misty.
Wind	Strong breeze to moderate gale from N.	Calm to gentle breeze from S. by E.
Sea	Short, moderate.	Smooth.
Average displacement, tons	726.8	746.2

PERFORMANCE, TEN HOURS, SIXTEEN-KNOT TRIALS.

Pressures:	*Warrington.*	*Mayrant.*
Average steam pressure at boilers, gage, pounds	248.5	249.0
pressure in lubricating-oil system, gage, pounds	18.8	13.2
pressure fuel oil to burners, boiler C, gage, pounds	204.0	155.0
pressure fuel oil to burners, boiler D, gage, pounds	204.0	155.0
Vacuum in condenser, starboard, ins. of mercury.	29.23	28.36
port, inches of mercury	29.23	28.38
Revolutions, or double strokes, per minute:		
Shaft No. 1, starboard	291.58	292.29
2, port	291.92	292.29
Average	291.74	292.29
Pumps, main air, port	27.0	42.6
circulating, starboard	200.0	213.0
port	200.0	221.0
feed, inboard	...	...
outboard	22.0	12.0
lubricating-oil, inboard	31.8	24.3
oil-cooler circulating	24.7	37.5
fuel-oil service, after fireroom	19.7	17.4
Forced-draft blower, one	714.0	818.0

	Warrington.	*Mayrant.*
Speed of ship, knots	16.266	16.265
Slip of propeller, in per cent. of its own speed, based on mean pitch:		
Shaft No. 1, starboard	8.43	8.78
2, port	8.54	8.78
Mean	8.485	8.78
Air pressure in fireroom, inches of water	1.38	1.45
Shaft horsepower:		
Shaft No. 1, starboard	803.0	748.4
2, port	804.0	696.4
Total	1,607.0	1,444.8
Indicated horsepower:		
Total auxiliaries in operation	153.0	...
Temperatures:		
Injection, starboard, degrees F	...	...
port, degrees F	37.0	59.8
Discharge, starboard, degrees F	75.0	71.8
port, degrees F.	51.9	75.4
Feed to heater, degrees F	66.4	61.4
from heater, degrees F	189.7	66.5
Main steam, degrees F	397.2	403.4
Engine-room air, degrees F	69.6	91.3
Outside air, degrees F	27.9	66.3
Fireroom air, degrees F	73.1	105.0
Fuel oil to burners, boiler C, degrees F	174.5	132.0
D, degrees F	157.0	132.0
Smokepipe gases, degrees F	562.0	428.0
Fuel oil:		
Specific gravity	0.899	...
Deduced data:		
Square feet of heating surface per S.H.P.	5.6	6.229
Cooling surface (main condensers), square feet per S.H.P.	6.225	6.924
During above trials the following auxiliaries were in operation:		
Main air pump	1	1
circulating pumps	2	2
feed pump	1	1
Forced-lubrication pump	1	1
Oil-cooler circulating pump	1	1
Fire and bilge pump (sanitary)	1	1
Oil-fuel pump	1	1
Oil-tank pump (at times)	1	1
Feed heater	1	not used*
Dynamo	1	1

* Auxiliary exhaust going, sixth stage.

During above trials the following auxiliaries were in operation:	*Warrington.*	*Mayrant.*
Forced-draft blower	1	1
Steering engine, as required	1	1
Steam to galley	used	used
heating system	used	not used
Boilers C and D	2	2
Burners, boiler C	3 to 4	4
D	3 to 4	4

TEST OF ANCHOR GEAR.—"WARRINGTON."

On this test an anchor was let go in about 25 fathoms of water, and the chain was veered to the bitter end. Before starting the test a few fathoms were hove in to bring the 90-fathom shackle to the hawse pipe. Total time of heaving in 90 fathoms, 12 minutes and 52 seconds. Rate of heaving in, 7 fathoms per minute.

MANEUVERING TRIALS.—"WARRINGTON."

TURNING TRIALS.

(*a*) The helm being amidships, the order was given "Hard-a-port." The following observations were made:

Time to shift wheel on bridge, seconds	5.8
Times at rudder head:	
Amidships to 25 degrees port, seconds	3.0
30 degrees port, seconds	6.0
33 degrees port, seconds	9.0
Time to swing 360 degrees change of course, minutes and seconds	3:27.0

Estimated diameter of turning circle not obtained, because of darkness, but was rather large.

Initial angle of heel (to starboard or inward), 5¾ degrees, influenced by wind and sea.

Final angle of heel (to starboard or inward), 1½ to 3 degrees, influenced by wind and sea.

(*b*) The helm was then shifted from "hard-a-port" to "hard-a-starboard." The following observations were made:

Time to shift wheel on bridge, seconds..... 7
Times at rudder head:
33 degrees port to amidships, seconds..... 5
to 25 degrees starboard, seconds..... 8
to 34 degrees starboard, seconds..... 10
Time to swing 360 degrees change of course, minutes and seconds..... 3:42
Estimated diameter of turning circle not obtained, because of darkness, but was rather large.
Initial angle of heel (to port or inward), 2 degrees, influenced by wind and sea.
Final angle of heel (to port or inward), ½ to 2½ degrees, influenced by wind and sea.

(*c*) The helm was then shifted from "hard-a-starboard" to "amidships." The following observations were made:

Time to shift wheel on bridge, seconds..... 3.2
Times at rudder head:
34 degrees starboard to amidships, seconds..... 2½

This completed the steering tests with the vessel going ahead.

The speed of the vessel during the above trials was 30 knots.

BACKING TRIALS.

The helm being amidships and the vessel making approximately 30 knots, the engine telegraphs were thrown "full speed astern." The following observations were made:

Time from signal to dead in water, minutes and seconds..... 0:55
in engine room, taken from the time the signal to reverse was received:

	Starboard.	*Port.*
Began turning over astern, seconds.....	20	21
Full speed astern, minutes and seconds.....	1:20	1:25
Revolutions per minute astern.....	420	420

The indicators were then thrown "full speed ahead." The times observed in the engine room, taken as above described, were:

	Starboard.	*Port.*
Began turning over ahead, seconds.....	15	16
Full speed ahead, minutes and seconds.....	1:03	1:03

REMARKS.

There are several features in connection with the use of oil fuel which attract attention. In the first place, the ease and dispatch with which the supply can be replenished presents a striking contrast to the labor, dirt and general disturbance incident to the operation of coaling ship. Also the ability of the oil-supply pumps to transfer the oil from any tank into any other or overboard constitutes an agency of appreciable value for controlling the trim of the vessel, either in an emergency or under ordinary conditions. The reduction of labor in the firerooms, due to the ease and accuracy with which the combustion conditions can be adjusted and maintained to suit the power required, is particularly noticeable, in fact on the trials of the *Warrington*, which were run in winter, many of the fireroom force wore overcoats while on duty. With oil burners and throttle valves properly adjusted, there is a noticeable reduction, even when running at maximum power, of the feverish activity and strain on the part of the working force, which is so apparent in the case of a high-speed reciprocating-engine and coal-burning installation under the same conditions. During the trials of these vessels the smooth running of the turbines and shafting was a noticeable feature, the maximum vibration noticed under any condition being extremely slight for vessels of this type.

The author's acknowledgments are due to Lieutenant J. O. Richardson, U. S. N., Assistant Inspector of Machinery at the Works of the Babcock & Wilcox Company, and to Mr. J. W. Dawson, of the office staff of the Inspector of Machinery, Cramp's Shipyard, for the photographs illustrating this article.

THE MANUFACTURE OF SEAMLESS STEEL BOILER TUBES.

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School of Marine Engineering.

A seamless tube is one in which there are no joints or welds.

The history of the manufacture of seamless tubes dates from about 1837, when a process for their manufacture was patented by an Englishman named Hanson. In this process a short, thick cast-steel cylinder was heated to a high temperature, placed in a steel cylinder, and, under the pressure of a hydraulic ram, extruded through a die and over a mandrel in much the same manner that lead pipes are made.

In 1854 J. D. M. Sterling conceived the idea of casting hollow cylindrical steel billets and working them into seamless tubes by rolling, drawing or hammering, or a combination of these processes. A modification of this process was patented in 1867.

In 1882 R. Elliot patented a process similar to that of Hanson, except that he claimed that the metal was extruded with helically-arranged fibers. This is the first record of a belief in the desirability of helically-arranged fibers by the inventors of tube-making machinery.

The next process patented was the method of making seamless tubes by successive drawing operations on a cylinder formed by cupping a flat circular plate. This process is now in use at the works of the Babcock & Wilcox Boiler Company for the manufacture of seamless headers, and at the Christy Park plant of the Shelby Steel Tube Company for the manufacture of seamless pipe above $5\frac{1}{2}$ inches in diameter. This process produces the best seamless tube that can be

manufactured today, because the flat plate is a better material than the round billet, since it is more homogeneous, due to more working. There is also less variation in wall thickness of the finished tube, since the hole can be made more truly concentric than by any piercing process.

This process is not used in the manufacture of tubes smaller than 5½ inches in diameter, on account of the greater cost over the present piercing process.

Church & Harlow patented a swedging mill in 1841, but their process of manufacture was not successful until later modified.

Another method once extensively used was the Ehrhardt process of forming hollow billets, which consisted in placing a red or white-hot steel billet in a matrix of circular section and forcing a mandrel down through the billet, the heated metal filling out the matrix around the mandrel. A modification of this process was patented in the United States in 1904 by Rudolf Kronenberg. In the Kronenberg process, in order to prevent the heated blank from upsetting under the pressure of the mandrel, it is supported on the sides by a series of collars formed of pins which move out radially as the mandrel point approaches them, in this way providing space for the material displaced by the mandrel and all the time supporting the walls of the blank.

Seamless tubes have also been made by boring an axial hole through the billet and drawing the tube from the hollow billet so formed. This, of course, produces a tube with little or no variation in wall thickness, but it is a very expensive and wasteful process and is not used at present.

In 1885 the first patents were granted to the Mannesmanns. The specifications state that "the invention consists in the combination, with suitably adjusted diagonally-acting rolls having convergent working faces, of a cone-pointed mandrel, which is arranged to project a prescribed distance into the space between the working faces of the rolls, and hence to penetrate the center of the forwardly-progressing blank and to thereafter serve as an anvil or former, over the surface of

which the metal composing the blank is forced by the reducing and stretching action of the diagonally-acting convergent rolls, and is thus transformed into the tube, the interior diameter of which is determined by the diameter of the base of the cone, and the exterior diameter of which is determined by the width of the narrowest part of the space between the working faces of the rolls."

The Mannesmanns also state that "the process consists firstly in imparting to the piece to be rolled a rope-like twist as regards the outer fiber. For this purpose the blank or piece to be operated on is made to rotate between two plain discs or between two or more conically-shaped or otherwise formed rollers, and thereby to advance slowly. In consequence of the different speeds of rotation of the two ends of the blank a twist similar to that of a wire rope is imparted to the fiber of the rolled product."

About ninety-five per cent. of all the seamless tubing now manufactured is made by methods based on the Mannesmann process.

Modifications and improvements in the Mannesmann process of piercing billets have been made and patented by R. C. Stiefel, Charnock, Samuel Diescher, J. H. Nicholson and others.

As the production of the hollow billet is the most important and difficult process in the manufacture of seamless tubes it will be discussed more thoroughly than any other operation on the material.

The Mannesmann's process of piercing steel billets is based on the phenomenon of central rupture. If a heated cylindrical steel billet be placed on an anvil and struck a blow with a hammer the billet becomes elliptical in cross section at the point of impact, the horizontal diameter having been stretched; therefore a strain will be set up in the metal, as shown by the dotted arrows in Figure 1. If the billet be rapidly revolved about its axis, as the blows of the hammer are repeatedly delivered, each diameter that assumes a horizontal position as the blow is struck will be stretched and a strain will

be set up in the metal in the direction of every possible diameter, and, as a consequence, the center of the billet will be strained beyond the elastic limit and finally a small axial hole will be torn in the billet.

The discs, rolls or rollers of the piercing machine simulate the action of the hammer and anvil, and in adition are so shaped and placed as to draw the billet through the machine, once the operation is started. The hole torn in the billet is a small, ragged, irregular-shaped hole not exactly central or symmetrical, therefore the mandrel is used to assist in piercing the billet to increase the size of the hole and to smooth the inner surface of the pierced billet by welding down any thin edges or slivers of the torn metal.

Figure 2 shows one of the first forms of rolls used by the Mannesmanns. The two rolls in this, as in all other piercing machines, revolve in the same direction.

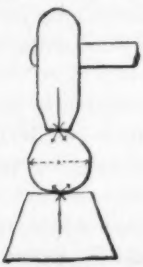


Fig. 1.

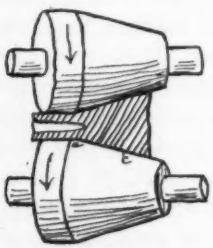


Fig. 2.

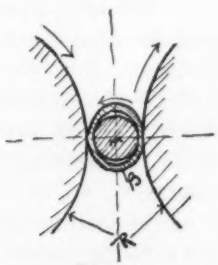


Fig. 3.

The billet is drawn into the piercing mill by the action of the rolls. If the action of the upper roll is considered it is seen that the action of this roll is such that it tends to move the billet bodily around with the surface of contact; but as the billet is prevented from changing the position of its center line by the guides (not shown) it is easily seen that this force may be resolved into two forces, one in the direction of the axial line of the billet and one (in a plane perpendicular to this axial line) perpendicular to the line of contact between the roll and the billet. As the billet is free to move under the influence of these two forces a motion of rotation and a

motion of translation through the pass is imparted to the billet.

The method of imparting the rope-like twist mentioned in the specification to the Mannesmann's patents is explained by reference to Figure 2. At each point along the pass of the rolls the speed of rotation of the billet is due to the peripheral speed of the roll. It is evident that as the billet approaches the throat of the pass *a*, Figure 2, where the diameter of the roll is largest and the peripheral speed is greater than the speed at the point *c*, the speed of rotation of the billet is greater than at the point *c*, therefore a twist is given the fibers of the pierced billet.

In addition to this great strain on the fibers of the billet, due to the twisting effect caused by the rolls, there is also the strain caused by rolling the billet over the mandrel.

Figure 3 shows a cross section of the rolls, billet and mandrel, the arrows showing the direction of rotation of the rolls and the billet.

The pressure of the rolls on the metal at the point of contact between the rolls and the mandrel forces the metal out in the direction in which it is free to move, and so forms an elliptical cross section, as shown. It is evident that severe strains are set up in the metal of the billet as it is pierced, due to revolving it through this elliptical cross section and constantly changing the radius of curvature of the walls of the pierced part of the billet.

These combined stresses are so severe that only very good steel of a special grade can be used in this process, and even with the best steel used any small defect is shown up greatly enlarged in the pierced billet.

The Mannesmanns at first considered it an advantage to impart a rope-like twist to the pierced billet, but manufacturers have since sought to reduce this unnecessary strain of the piercing operation.

Figures 4 and 5 show later forms of the Mannesmann rolls, and a sketch similar to Figure 4 was filed with their patent specification in 1887. The converging pass at the first part

of the pass serves to pierce the billet, and the diverging pass is to enlarge the hollow billet into a tube.

In describing the rolls shown in Figure 5 M. Mannesmann states that "these forms of rolls are capable of being so arranged with relation to the blank that the twist imparted to the fibers during the process of developing the tubular formation may be wholly or partially taken out during the process of enlarging the tubular formation."

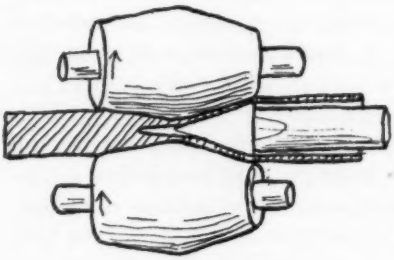


Fig. 4.

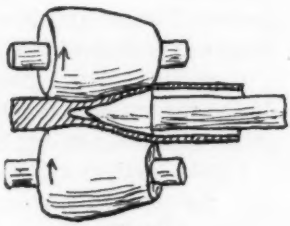


Fig. 5.

Figures 6, 7 and 8 show the Stiefel piercer patented in 1895. Figure 6 is a side elevation with some of the parts broken away to more clearly show the construction and position of the parts. Figure 7 is a plan view, partially in section, of a pair of discs, with a piercing mandrel in place and a blank or billet being pierced by the mandrel. *G*, *G* are the guides. Figure 8 is a plan of the piercer as constructed and used today.

The action of the discs of this machine is fundamentally the same as that of the rolls in the Mannesmann machines.

Figure 9 is a diagram representing one disc and its action on the billet in imparting to it a longitudinal motion through the machine and a motion of rotation about its axis.

The center line of the pass is below the center of the discs, so that as the disc revolves with the billet pressed against its surface the disc exerts a force on the billet in the direction *A*, but as the billet is held down by the action of the guides and the other disc this force *A* is resolved into two forces:

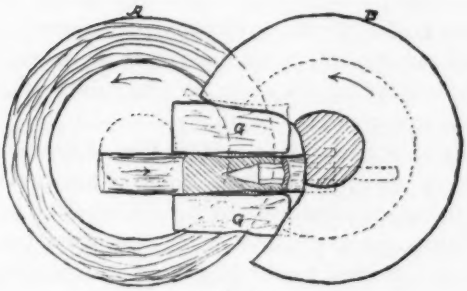


Fig. 6.

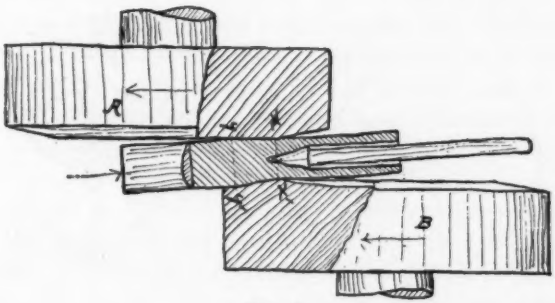


Fig. 7.

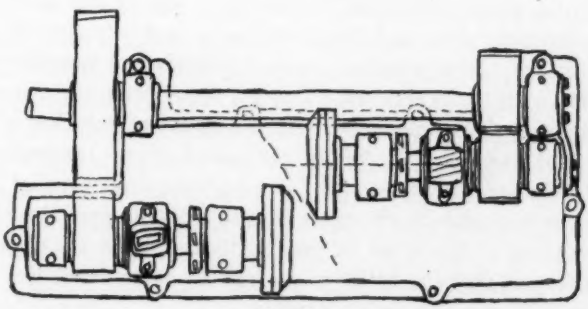


Fig. 8.

B revolving the billet about its own axis and *C* drawing it through the mill. As the guides may be adjusted in a vertical plane the center line of the pass may be moved in or out toward the center of the disc, so the speed of the billet through the machine may be changed.

Referring to Figure 7 it is evident that at the points *X*, *X'* the peripheral speed of the discs *A* and *B* are the same, and therefore the speed impressed by the discs on the billet is the same on both sides of the billet. At any other point of the pass, as that indicated by the line *Y*, *Y'*, the peripheral speed of the disc *A* is not the same as that of disc *B*, so that one disc tends to impart a greater speed of rotation to one side of

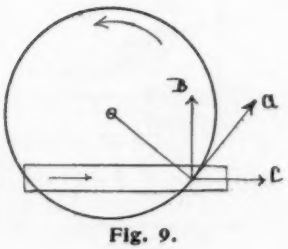


Fig. 9.

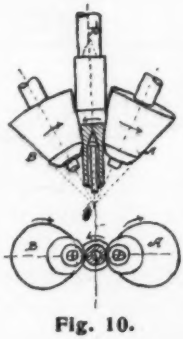


Fig. 10.

the billet than is imparted to the other side of the billet by the opposing disc, and therefore there is a slippage of each disc on the billet equal in amount, positive on one disc and negative on the other, and changing signs from the entrance to the exit side of the pass. As the speed of rotation of the billet at any point is due to the speed-giving tendencies of both discs and as the average speed-giving tendencies of both discs at any point is the same throughout the pass the speed of rotation of the billet is practically the same in all of its sections, so that the billet is pierced so as to leave the fiber practically straight throughout.

It would seem from Figure 7 that since the pass at *X*, *X'*

is smaller than at any other point of the pass the speed of rotation impressed on the billet at this point would be greater than at any other point of the pass, and that there would be a tendency to twist and untwist the fibers of the billet, as in the converging and diverging pass of the Mannesmann mill, Figure 5; but this is not the case, for at the section X, X' the billet has assumed an oval section, as shown in Figure 3, and its circumference at this point is larger than the circumference of a circle of diameter X, X', and is practically equal to the circumference at Y, Y', so that the speed of rotation at the two points is practically the same.

Figure 10 shows a form of piercing roll patented by R. C. Stiefel to overcome the slippage of the discs of his first machine, and at the same time preserve the straight fibers of the billet. This arrangement did not prove a success with the axes of the rolls and the center line of the pass meeting in a point, for there was not longitudinal motion imparted to the billet, and the ram R added to force the billet through the rolls did not work satisfactorily. The axes of the rolls were then skewed, so that the axis of each roll and the lines of the working face intersected on a line through the center line of this pass. This arrangement produced the drawing effect desired, and the ram R was not necessary, but still the mill as constructed was not a success, so that the piercer shown in Figures 6 and 7 has not been improved on.

The inventors and designers of piercing mills have sought to produce a machine that will not impart a twist to the fiber of the pierced billet, not because the billet with longitudinally-arranged fibers will give a better tube, but because the twisting of the fiber is a very severe test on the metal, and a mill producing a straight-fibered billet will not produce as many culls, and therefore from a given number of billets will produce more usable pierced billets than a mill producing billets with twisted fibers.

Mr. R. C. Stiefel says that he believes "that a tube with the fibers of the metal spirally located would be better than a tube with the fibers parallel with the axis of the tube, pro-

viding the tube had only to be submitted to internal pressure;" but in no case does he believe a tube with spiral fiber is preferable to a tube with straight fiber if in the production of such spiral location of the fiber the cohesion between the fibers or molecules of the metal has been destroyed, which must be and is necessarily the case by first twisting and afterwards untwisting the billet from which the tube is made.

The practical advantages of the Stiefel mill, Figures 6 and 7, over any Mannesmann mill are that the Stiefel mill produces much less scrap, is much simpler in construction, much less costly to build, less liable to breakage, much more easily adjusted and does not require as great skill to produce usable pierced billets.

SEAMLESS TUBE MANUFACTURING.

The manufacture of seamless steel tubing can be divided into two main steps: first, the manufacture of the round billets; second, the finishing of the round, solid billet into a seamless tube.

The manufacture of seamless tubing differs from the manufacture of any other article of steel in that in the manufacture of ordinary articles of steel the metal is compressed at every step in the process of manufacture from the steel ingot down to the finished article, the metal being supported all around as it is compressed, while in the piercing operation this condition is reversed, for the solid billet is pierced at the center, the metal being displaced from the center to the outside of the billet without an all-around outside supporting surface. Therefore, the very best steel must be used in the manufacture of seamless tubes, for any blow hole, crack or check in the ingot that would roll down and be eliminated or passed unnoticed in an ordinary article of steel would, through the expanding of the piercing operation, develop into a defect rendering the pierced billet unusable.

Basic open-hearth steel of about the following analysis is used for boiler tubes:

Si, ...	up to .20 per cent.
S, ...	under .04 per cent.
P, ...	under .03 per cent.
Mn, ...	.40 to .60 per cent.
C, ...	.14 to .19 per cent.

Only the production of the tube from the billet will be considered here.

The round, solid billets used in the manufacture of seamless boiler tubes vary in size from billets 2½ inches in diameter, weighing 30 pounds, up to billets 5 inches in diameter, weighing about 160 pounds. The size of the solid billet used depends upon the size and length of the finished tube to be made.

In some tube works the first operation is to center one end of the billet by drilling a hole about one inch in diameter and one-half inch deep in the end of the billet. This hole is to start the rupture in the axial line of the billet and to assist in making the hole concentric.

Whether the hole is drilled or not depends upon the practice of the tube works and on the size of the billet. In some works the center of one end of the billet is marked by a punch hole made by a conical punch when the billet is heated.

The next operation is to heat the billet in a furnace to a temperature of about 1200 degrees C., and from the furnace the billet passes to the piercing mill. The billet passes through the piercing mill in from three to five seconds and comes out a rough pierced billet. The twist of the fibers varies from one turn in eighteen inches of length at the Monessen works to practically straight, or at most one turn in thirty inches length, at Elwood City.

The piercing operation, involving as it does a reduction in the sectional area of the metal of, in many cases, seventy per cent., must necessarily produce hollow billets having considerable variation in size, with the surface more or less corrugated.

The pierced billet is stripped from the rod of the piercing

mandrel, either by hand or machine, and the pierced billet is ready for the next operation. In some cases the billet is reheated, and in other works the operations are continuous.

The hollow billet is now rolled over a mandrel to reduce the outside diameter, to reduce the wall thickness and to smooth up the outside surface of the billet. At the Elwood works, where only small tubes are made, the pierced billet is threaded on a mandrel about $1\frac{1}{4}$ inches in diameter and run through a continuous roll mill with three sets of horizontal and three sets of vertical rolls, then through a reeling machine to slightly enlarge the inside diameter of the tube so that the mandrel can be withdrawn.

The manner of carrying out the process of rolling the pierced billet varies in different tube works, but the results are about the same.

After rolling, the next operation performed depends upon whether the tube is to be finished as a cold-drawn tube or a hot-finished tube.

COLD-DRAWN TUBES.

The pierced and rolled tube is pointed at one end, either under a hammer or between rolls, and cut off flat on one side. A section of the pointing rolls is shown in Figure 11.

Fig. 11.

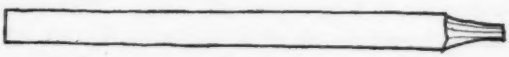


Fig. 12.

After the tube is pointed, as shown in Figure 12, it is allowed to cool down and is then pickled in a hot dilute sulphuric-acid solution to remove all scale and thoroughly clean

the tube. When the tube is removed from the pickling solution it is washed, then immersed in a solution of some lubricant, usually a dope made up of soap, refuse and tallow.

After doping the tube is taken to the draw benches and drawn through a hardened-steel or chilled cast-iron die and over a hardened, tempered-steel mandrel, the position of the die and mandrel being shown in Figures 13 and 14.

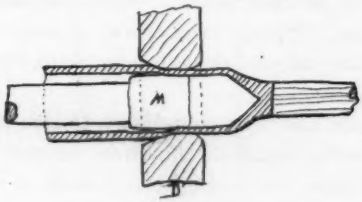


Fig. 13.

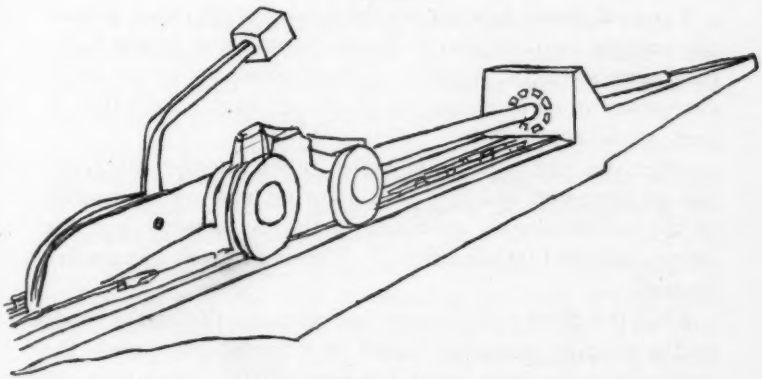


Fig. 14.

The tube is gripped at the pointed end by the tongs of the traveler on the draw bench, and an endless chain traveling along the bench draws the tube through the die when the hook of the traveler is engaged in a link of the chain.

The tube is drawn through the die at a speed of from fifteen to thirty feet per minute, the reduction in area being from 16 to 25 per cent., depending on the size and gage of the tube.

The tube leaves the die with the surface bright and smooth,

the smoothness and brightness depending on the amount of reduction in area. After the tube has been drawn the metal is very hard and brittle, therefore the tube is annealed at a cherry-red heat to remove the effects of the cold-drawing operation. The best annealing furnaces are fitted with pyrometers for accurately measuring the temperature, and dampers for regulating the heat, so that exactly the desired temperature may be maintained. After annealing the operations of pickling, doping, cold drawing and annealing are repeated until the last cold draw produces the desired diameter and gage.

When the tube has been cold-drawn to size and gage it is given the annealing finish at the lower critical temperature, then cut to length and straightened and is ready for test, inspection and marking.

The cold-drawn tube shows the following physical properties: elastic limit, 27,000 to 32,000 pounds per square inch; maximum strength, 49,000 to 54,000 pounds per square inch; elongation in eight inches, 24 to 28 per cent.; reduction in area, 50 to 60 per cent.

After the first cold draw, boiler tubes intended for Navy use are inspected, and any tubes showing laps, seams or welds on the outside surface are taken to the file benches and the defects removed by hand filing. This is a slow and expensive process.

After the third cold-drawing operation all the marks made by the piercing operation should be removed, but unless the workman at the draw bench has been careful to see that the mandrel and die are smooth and clean the tube may be scratched by a small, rough edge on either the die or mandrel, or by the presence of some hard, foreign substance, as a chip of steel or grain of sand. If the tube is drawn too rapidly the outer surface is marked by chatter marks as the tube jumps in the dies.

The table below shows the practice of several tube works in regard to size of billet and dimensions of tubes at different stages in the process of manufacturing boiler tubes.

Solid billet.		Pierced billet.		Rolled billet.		Number of cold draws.	Finished tube.		Works.
Diameter.	Weight.	Inside diameter.	Wall thickness.	Outside diameter.	Wall thickness.		Diameter.	Gage.	
ins.	*lbs.*	*ins.*	*ins.*	*ins.*	*ins.*		*ins.*	*ins.*	
$2\frac{1}{2}$	30	$1\frac{13}{16}$	$\frac{9}{16}$	...	...	4	1	12	Morado.
$2\frac{3}{4}$	30	$1\frac{5}{8}$	$\frac{9}{16}$	$1\frac{11}{16}$	$\frac{9}{16}$	5	1	12	Elwood.
$2\frac{3}{4}$	30	$1\frac{5}{8}$	$\frac{5}{8}$	$1\frac{3}{4}$	$\frac{7}{32}$	5	$\left\{\begin{matrix}1\frac{1}{8}\\1\frac{1}{4}\end{matrix}\right\}$	11	Elwood.
3	72	$2\frac{1}{4}$	$\frac{3}{4}$	$2\frac{3}{4}$	$\frac{1}{4}$	3	2	8	Standard.
3	...	$3\frac{3}{8}$	$\frac{1}{4}$	...	...	3	2	8	Morado.
4	...	$4\frac{5}{16}$	$\frac{5}{16}$	...	...	3	4	6	Morado.
$4\frac{1}{2}$	160	$3\frac{7}{8}$	$\frac{9}{16}$	$4\frac{1}{2}$	$\frac{11}{32}$	3	4	6	Monessen.
5	155	$3\frac{13}{16}$	$\left\{\begin{matrix}\frac{5}{16}\\\frac{7}{16}\end{matrix}\right\}$	$4\frac{1}{2}$	$\frac{11}{32}$	3	4	6	Standard.

HOT–FINISHED TUBES.

The process of manufacturing hot-finished boiler tubes has been developed in this country by the Shelby Steel Tube Company in their Standard plant, and at present is used in the manufacture of only the larger-sized tubes.

After the pierced billet has been rolled it is transferred to the reeling machine, which rolls down any scratches or laps on the inside of the tube and removes all scale, giving the tube a smooth-finished surface.

The rolls of the reeling machine are shown in Figure 15.

The action of the rolls in drawing the tube through the machine is the same as in the piercing machine. The mandrel revolves with the tube. The reeling machine is driven by an electric motor and the machine is fitted with an ammeter placed directly in front of the operator so that he can tell by the reading of this ammeter the amount of current the motor is taking, thereby knowing the power the motor is developing and the pressure exerted on the tube by the rolls, so that he is able to adjust the rolls so that the proper pressure is maintained at all times.

From the reeling machine the tube passes to the sizing rolls, where it makes two passes which reduce it to the exact size of the finished tube plus a known allowance for shrinkage.

After sizing, the tube goes through a cross-roll straightener fitted with long parabolic rolls, as shown in Figure 16. These rolls are mounted one above the other with their axes at an angle of about 27 degrees in a horizontal plane.

From the cross roll the tube goes to the cooling table, where it is rolled over slowly as it cools so as to keep it straight.

After cooling, the tube is cut to required length, inspected and tested, and is then ready for marking and shipping.

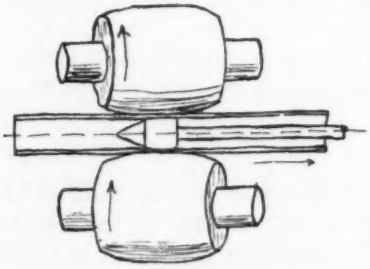


Fig. 15.

Fig. 16.

From the manufacturing view point the hot-finished tube is superior to the cold-drawn tube because the tube is finished from the hot billet to the finished tube in one heat and nearly all the work is done by machinery, so that the cost of production is very much less, and the time required to produce a finished tube is reduced from several days to a few minutes.

Naturally the manufacturers of hot-finished tubes would urge their adoption and use because of the reduced cost of manufacture and because they are the only tube works in this country so well equipped for manufacturing hot-finished tubes.

If a hot-finished tube be placed on benches and struck light blows with a hammer it will be found that many small slivers and threads of metal have been detached from the inner surface of the tube, leaving small grooves and checks in the surface. It is probable that this inherent defect of the hot-finished tube would cause many rejections if the tubes were submitted to test by Navy boiler-tube inspectors, these rejections causing the cost of each accepted hot-finished tube to be much higher than the actual cost of manufacture. The pickling of the cold-drawn tube removes the slivers and scale, and the cold-drawing operations smooth up the inside surface.

The outside surface of a hot-finished tube receives a fine finish and looks to be as good as the surface of a cold-drawn tube.

The hot-finished tubes made from good material show the following properties: elastic limit, 36,000 to 42,000 pounds per square inch; a maximum strength of 56,000 to 62,000 pounds per square inch; elongation eight inches, 18 to 22 per cent.; reduction in area, 50 to 60 per cent.

Many users of boiler tubes are strong believers in the hot-finished tube, and Mr. J. L. Ford, of Chicago, the chief inspector of the Hartford Boiler Insurance Company in that district, says he would rather take a risk on boilers with hot-finished tubes than with cold-drawn tubes.

The great advantage a hot-finished tube has over a cold-drawn one is that it is finished at one heat and does not require annealing.

If a few hot-finished, four-inch tubes were installed in a B. & W. boiler fitted with cold-drawn, two-inch tubes the results of such a test might be uncertain, for the different treatment to which the metal of the different tubes had been subjected might cause one kind of tube to corrode more rapidly in the presence of the other than either would if the whole boiler were equipped with the same kind of tube. It is probable that two-inch, hot-finished tubes will soon be available, and then a test of two boilers under the same conditions, one fitted with cold-drawn and the other with hot-finished tubes, would be of great value.

THE SCIENCE OF MANAGEMENT.

By Lieutenant G. J. Meyers, U. S. N.

"There is always a best way of doing everything—if it be to boil an egg."
—Emerson.

When we consider any activity in life which has something definite for an object we call the direction of the process through which we accomplish that object, management. Management is the application of skill or care in the conduct of an enterprise or operation. Most people have considered that there are various kinds of management—poor, indifferent, fair, good or excellent. But it has never been considered that these various qualities of management depend upon the violation or non-violation of certain laws that belong to management and make it a science.

The quality of management is usually measured by the results accomplished and by its cost in time and money. Since it is possible to manage any activity and to obtain the most successful result, some laws must govern this successful management. The laws of any science are based upon experiments to determine relations between certain phenomena. This is so in the science of management as well as in the sciences of chemistry, physics, engineering. Theories are not being considered, but laws based on experiment, practice and common sense, and accepted as laws because of their success when applied to the subject they cover. To show that management has its laws and that the observance of them will bring about the most successful results and reduce to a minimum losses of time and money is the object of this paper.

Success cannot be obtained in management any more than in other sciences if the laws that govern it are violated. The quality of the management depends, then, on the extent to which its laws are observed.

The laws as here recorded are not the result of an arbitrary summing up of how an activity should be managed, but are deduced from a careful analysis of the management of several successful manufacturing companies. After applying them carefully to these companies they have been applied to activities ranging from the cooking of a meal to the conduct of a war. And it is necessary to emphasize the fact that these laws when applied give most successful results; and, vice versa, where successful results are obtained it will be found that these laws are applied.

Some objection has been made to treating the laws in the following form, omitting methods. To anyone who has had any experience in management it is perfectly obvious that to record methods or procedure would be more than a life work. Every industry has its own methods, and in every branch of every industry different methods are required. In three successful machine shops visited by the author each had different methods of carrying out the laws, though each was engaged in machine metal work, manufacturing different lines of machines, and all three were equally successful.

What has been attempted is to put the subject of management in a form such that it can readily be understood by anyone engaged in managing without hiring an "expert" or spending most of his time in reading what has been written on "Scientific Management," and to show that there is a wide difference between the laws and principles of management and the method of carrying out these laws. The *methods* are very often stated as fundamental principles when they are not. It is hoped that anyone who is managing may, by carefully observing the laws in his business, soon evolve or find the methods that are best suited to his business.

It must be remembered that there are cases where not all the laws can be applied in all their details, but that in these cases, were it possible to apply them in detail, a nearer approach could be made to perfection of results than if the laws were neglected.

SYNOPSIS OF LAWS.

Law I.—What to do.
Law II.—Instructions before work starts.
Law III.—Machines and tools.
Law IV.—Workmen.
Law V.—Insure instructions are carried out.
Law VI.—Costs.
Law VII.—Study for improvements.

LAW I.

It is necessary in any activity to have a complete knowledge of what is to be done and to prepare instructions as to what is to be done before the work is started.

It must always be known what object is desired to be accomplished before starting work. For example: (1) In constructive manufacturing it is necessary first to design the finished product and to issue drawings of the design. (2) In the manufacture of chemicals or compounds it is necessary to state what the finished product is to be and to write down the specifications of the finished product. (3) In the case of professional work it is necessary to designate the object: for example, in medicine, a patient is to be cured of disease or sickness, and it is necessary to record either on paper or on the brain what the cure is to be. (4) In any one-man activity it is necessary to state the object that it is desired to accomplish; for example, in inventive or experimental work the ultimate purpose should be known as nearly as possible before work starts. Very often it will be found that the stating of the object is the same as writing the instructions as to what is to be done.

Whenever the first law of management is applied loss of time and money is eliminated as follows:

What is to be done is planned before the work starts and the laborer has only to follow directions. He need not stop to think what his past experience in similar cases has been, nor need he consult with a foreman and lose time in that way,

but his instructions what to do are definite. The management is not paying a man to do a certain kind of mechanical work and requiring him to occupy his time in designing something he is not fitted to do. If the workman is losing his time in thinking about what should be thought out for him, and not accomplishing what he is hired to do, he is increasing the time he gives to producing his work and thereby increasing costs and reducing output.

If we do not know what we want to do or if we do not tell the workman what to do there is a vast amount of misapplied effort, there is a groping for something, which means that no effort is applied through a space of time; there is the idle workman we are paying who is waiting to be told what to do, and wasting time in studying the poor instructions he often does receive even after he thinks he has started on the work. All of this means waste of time and waste of money.

As this law demands that the object of any activity should be stated and instructions covering what to do should be written, it is obvious almost without explanation how this law is applied. As an example: A company manufacturing machines wishes to make one for a certain purpose. The order goes to the drawing room to design this machine; in issuing this order the object is stated. The drawing room then designs the machine and commits the design to paper in the form of general plans and detail plans; thus the instructions what to do are written.

LAW II.

It is necessary in any activity to prepare detailed instructions for each operation that goes to make up the whole as to how, when, where, and in what time each should be performed, what tools, and what materials to provide before work starts, and to transmit these instructions with the necessary tools and materials to the workman before the work starts. The stock of material on hand should not be allowed to fall below a certain minimum determined by the rate of output.

This law covers the planning of each operation and routing

it through the shop. It simply means that the determination of how, when and where the work is to be performed, and what materials and tools to provide, is taken out of the hands of the workman and foreman and put into the hands of the planning department, where all the data as to the date of delivery, past methods, etc., can be drawn on to make accurate and definite instructions. The work is planned and instructions are given after a careful study from past experiment and practice as to the best way in which to do that work. Here the judgment of the laborer is eliminated. The amount of time and money saved in this can be judged by considering that every workman if left to himself will do the work according to his judgment, and it will be found that there are as many ways of doing a piece of work as there are workmen to do it. The chances, then, are that a large majority of the workmen are not doing the work in the best way.

The application of the second law of management will tend to improve the methods of the workman and to reduce loss of time in the following ways:

(1) The time the work is to be started is planned before the work starts, so that in producing a complicated machine the parts are finished as they are needed to make up the whole. The workman who is fitting the parts or whose work depends upon the finishing of some part by others need not remain idle while he is waiting for the others to finish a needed part. Thus erecting work or work depending on other workmen will not be interrupted by allowing guess work to determine *when* the work is to be started, and, consequently, the calculations as to when the finished product is to be delivered to the purchaser will not be guess work. The instructions as to when the work is to be started are definite and exact, and are made with due regard to the work as a whole and to keeping all machines equally busy, and they eliminate losses in time due to delays and confusion.

(2) The machine at which the work is to be done is indicated in the instructions after careful study before the work is started, having regard for the suitability of the machine and

for the even distribution of work among the machines. This results in eliminating loss of time due to confusion and idleness at any one machine, and the instructions covering it are made definite and exact before the work is started; none of this is left to the judgment of the foreman or the workman.

(3) The time which it should take to do any piece of work is transmitted to the workman before the work starts. This time is based upon careful time study of previous operations where all unnecessary motions have been eliminated. It should be a reasonable time in which the work can be completed over and over again for a year, if necessary, without spurting but with the man working at his normal or rational capacity. It is fixed also with regard to the quality of the work desired.

(4) By having the tools and materials for each job provided at the place the work is to be done before the work starts the loss due to idleness of machine and of workman while the tools are being brought is eliminated. The tools and materials are definitely stated in the instructions for each job, and the tools and materials for one or two subsequent jobs should be ready for the workman to proceed promptly on those jobs.

(5) All instructions are made concise, exact and easily understood, and are at the place at which the work is to be done, so that before a workman is through with one job he has on hand, in addition to his tools and materials for the next job, the written instructions as to what he is to do, how, when, where and in what time he is to do it.

The elimination of losses of time explained in the last five paragraphs may be said to be the result of planning and issuing of instructions for any job before that job is started and are covered by Law II.

On the other hand, if Law II is not observed losses are increased as follows:

(1) If the workman does not know how he is going to do a certain thing he is going to waste considerable time finding out, and is going to take up a great deal of his own time and of the time of some one else who should be otherwise engaged,

and, finally, if he thinks he can do it without definite instructions, we are relying on his judgment as to how it should be done, which may be wrong.

(2) If the workman has no instructions as to when to start a piece of work he is likely to let the most important piece go and take up any other at hand, or he may rely upon the judgment of the foreman as to when it should be started. In either case if we are, for example, constructing a machine, one part of the machine may be neglected until all others are ready for assembling. Then the unfinished part must be rushed through to the neglect of other work, and in the meantime our erectors are waiting, and the customer is not getting his machine when it was promised him. A little thought will show what confusion and loss of time will result from this practice.

(3) If the workman has no instructions as to where the work is to be done work is likely to crowd one machine and be slack at another, much to the neglect of the work at the crowded machine and to the increase of confusion in the shop. Machines are idle and men are idle, and, as in the last paragraph, the finished product is delayed in leaving the shop.

(4) If the workman does not know what time he is to consume on a given piece of work he will probably increase the number of unnecessary motions for that work and thus increase the amount of time it takes to do it. This results in loss of time and money. And there may be further loss due to the workman loafing at his work. This is perhaps one of the greatest losses in modern manufacture, though other factors, as is readily seen, help to increase the total loss.

(5) If the workman does not have his tools and materials ready to start on his next job before he is ready to proceed with it, there will be delay incident to obtaining the tools and materials. This also increases labor losses.

(6) If the workman has not his instructions as to what to do, how, when, where and in what time to do it, before he is ready to start his next job, there is another delay incident to

his getting these instructions either from the foreman or from the office. This again increases labor losses.

The application of Law II may be said to cover all the planning before the work in the shop is started. The planning is based upon the written instructions as to what is to be done which are made out under Law I. The functions of Law II will be as follows:

(1) Write instructions as to where the work is to be done. This should be done by analyzing the instructions as to what is to be done and dividing each complete job into groups and determining in what machine the operations in each group should take place and the order in which they should take place in relation to one another. This is done by the *route clerk.*

(2) Write instructions as to what materials and tools should be issued for each operation covered in (1). This is done by the *material and tool clerk.*

(3) Write instructions as to how each operation is to be performed. This is based on previous data properly classified for ready use. These instructions are written by the *instruction-card clerk.*

(4) Write instructions as to the time in which work should be done with regard to standard quality. This information is based on previous data and time studies properly classified for ready use. These instructions are written by the *instruction-card clerk.* Data is obtained by the time-study clerk, if there is one, under Law VII.

(5) The instructions are next collected and placed in a route file. This is the duty of the *route-file clerk,* who places the instructions in the route file, arranging all operations for one complete job in an indexed file book and giving the instructions for each operation one page in this book. These instructions are now arranged ready for the work to progress through the shop.

(6) Give instructions as to when work is to be done. This is done by the *production clerk,* who is over the other clerks in the planning department.

(7) Instructions in one, two, three, four, five and six are finally transmitted to the shop by the *order-of-work clerk* (of which there may be several in a large shop) from the route files covering each complete job divided into various operations. The order-of-work clerk must necessarily be familiar with the machines and men in the shop and with information as to when the finished product is to be delivered.

(8) The order-of-work clerk may have an assistant, whose duty it is to issue and receive operation cards to and from the workmen, and to record in the route file on the route sheet for each operation when the instructions for each operation are completed.

(9) The tools are provided by a boy in the shop after the tool list is sent to the machine.

(10) The materials are gotten ready for issue by the storekeeper before the instructions for work are sent into the shop. As soon as the materials are ready and the instructions sent into the shop an instruction card is sent to a *move man* in the shop to move the material to the place at which the work is to be done. This applies also to work done at a machine by one man, which must go to another machine and man for another operation.

(11) The materials are checked as soon as the issue order is given to the *storeroom keeper,* by the *balance-of-stores clerk,* who never allows material on hand to get below a certain minimum fixed by the demand for each material.

In this way, then, the workman has instructions, tools and materials, at the place at which the work is to be done before the work starts and there remains only the operation order for the work to start, which is issued by the order-of-work clerk. When one operation is finished the next operation order is issued by the workman, and the work continues.

In considering the application of this law most manufacturers think that it requires too much clerical work for the object. It is not meant that one man is always necessary for each function under this law, but that each of these functions must be performed. For instance: the route clerk can write

instructions for routing out material and can also issue orders and tool lists; the instruction-card clerk can write instructions as to how to do work and act as time-study clerk. The division of labor depends entirely on the nature of the activity and the size of the shop, having due regard to giving no man more work than he can expeditiously and efficiently handle.

LAW III.

It is necessary to provide for any given purpose before the work starts: (a) *The best tools and machines for that purpose;* (b) *the best arrangement of machines in their relative positions;* (c) *machines and tools in the best possible condition.*

Through experiment and practice in almost all industries machines and tools have been found that do better and quicker work than other machines and tools, and, in order to obtain maximum speed and highest quality of output, it is necessary that the best machines and tools should be provided and kept in the best possible condition at all times. It is evident that this requires that the machines and tools provided be of one standard—the highest.

It is desirable to arrange machines with regard to the work they perform, in order to reduce time and labor cost of moving work from one machine to another.

By applying this law losses are reduced as follows:

(1) The best machines and tools are provided for doing any job. This means, for example, that a machine that will do two operations at once is better than the machine that does them in succession, and that automatic machines are better in a great many classes of repeat work than hand-tended machines. And it means that there are tools that are best fitted for any particular class of work, and even of these there are some that have been found by experiment and practice to be the best tools. The best tools, then, should be the only ones kept in stock. It is evident, then, by having the best tools and machines, loss of time is eliminated by reducing the time of

each operation or series of operations, and by improving the quality of the finished product and thus decreasing waste due to defects in the finished product.

(2) Arranging machines in relation to one another so that time is not lost and labor is not increased by transferring work from one machine to another further eliminates loss of time and money.

(3) By keeping the tools and machines in the best possible condition loss of time is eliminated; since the machine is able at all times to deliver its maximum power at its maximum speed, there is no necessity of changing the tool because it is not sharp or is soft, or is not the standard of the best, and the possibility of a machine breaking down in the middle of work and delaying that work and keeping the workman idle is minimized.

The application of Law III is as follows:

This law should be carried out partly before any work is done; that is, the best tools and best machines should be provided before the work is undertaken, by studying machines already in operation and seeking machines with the latest improvements. They should be arranged in the shop in relation to one another to make the progress of work from one machine to another as nearly continuous as possible.

While work is in progress the tools should be kept shaped and ground, the machines should be kept clean and in good working condition, and belts should be kept at a tension such that the machines will deliver maximum power at maximum speed.

A record of overhaul and repairs to belts and machines, and a routine for overhauling and testing will be found to greatly reduce breakdowns and consequent delays.

For testing, inspecting and overhauling belting there should be enough men to completely carry out the routine, but they should be kept busy during working hours on idle machines. When necessary, they should work during the noon hour and for an hour after work stops in the afternoon, they being paid extra for this time.

The general repairs, including care of belting, are carried out by a regular gang under the charge of a repair boss. Those repairs that are urgent are, of course, effected first, and a complete record of all repairs is kept in a place available to the production clerk.

Law IV.

It is necessary in any productive work to (a) *select the best laborer for the work demanded,* (b) *to keep the laborer so selected at his work and at no other.*

Men should be selected for particular work who have abilities for that work; as a rule, they can perform that work better than any other. Where a man persistently falls down in the quantity and quality of his output he should be either discharged or transferred to work that he is better qualified to perform.

After a man is selected for and proved at any particular work he should not be required to do any other class of work. For instance, a machinist should be kept at machinist's work and not be required to do blacksmith's, messenger boy's or tool grinder's work.

Losses are eliminated by applying Law IV as follows: The man best qualified should be selected for the work, having due regard to the cost of his labor. It is evident that it would be poor policy, and would result in poor workmanship and loss of time, to employ a blacksmith for a machinist's job, or to employ a machinist at machinist's wages to do the work of a messenger boy. It is important to keep a workman at the work he is required to do. It is evident that money and time are saved by employing a low-priced boy to carry the tools and materials to a high-priced machinist, and by keeping that high-priced machinist employed at machinist's work every minute that his labor is being paid for.

Law IV may be applied as follows:

The selection of the best man for work must be based on a consideration of the man's trade, the kind and class of skill

required for the work, and, above all, the physical fitness of the man for the work.

LAW V.

It is necessary in any activity to assure that instructions are carried out as work progresses as to (a) *what is to be done,* (b) *how,* (c) *when,* (d) *where,* (e) *in what time work is done,* (f) *whether tools are provided,* (g) *whether materials are provided,* (h) *whether tools and machines are kept in best possible condition.*

It is as necessary for the management to know whether the instructions it issues are carried out as it is to issue instructions. Each function of this law may be carried out by a man detailed for the purpose, or two or more functions may be performed by one man. The *methods* may be selected, depending on the industry, and on the decision of the improvement expert, after a careful study of the men, the functions and the methods.

By applying Law V losses are reduced as follows:

(1) Having bosses in the shop. If a workman is slow in setting up his work the gang boss should instruct him to improve his time; if a workman does not follow the instructions for speed the speed boss should show him how the instructions should be carried out and the work done faster.

(2) As a further incentive to having instructions carried out, particularly as to the manner and time in which work is to be done, a bonus is offered to the workman to do the work in the time allotted and to produce a standard quality of work. This incentive tends to reduce the time in which to do any job, and results directly in a high bonus to the owners as well as better wages for the laborer.

(3) In order to prevent waste due to poor workmanship an inspector examines the finished product and requires it to be of standard quality. If it is not, the workman losses part of his bonus for fast work; this reduces loss due to poor workmanship.

(4) Finally, a routine for overhauling machines and for

reshaping and grinding tools will insure that the machine and tools are kept in the best possible condition; records are kept as to whether or not this routine is being carried out, and in all cases where breakdowns occur immediate repairs are made and reported. Usually the repair and upkeep of tools and machines would be performed by men who do nothing else. This eliminates loss due to breakdowns and failure of machines to deliver their maximum power at maximum speed.

In its application this law brings us back to the work in progress in the shop and is a connecting link between the shop and the production clerk. It requires reliable men in the shop to see that work progresses according to the instructions and to report on this work, and will include the following functions:

(1) Proper tools and materials supplied.

(2) Work is set up properly.

(3) Instructions as to speeds, depths of cut, speed of cut, etc., are observed.

(4) The work is done in specified time.

(5) That machines and tools are kept in best condition.

(6) That finished product is of a standard quality.

These functions are performed by—

(1) Gang bosses, who inspect and report on the functions (1), (2) and (5).

(2) Speed bosses, who inspect and report on the functions (3) and (4).

(3) Inspectors, who inspect and report on (6).

The same rule applies here as under Law II, that the functions that are performed must be regarded, and that it is not necessary to have a man for each different function. That will depend on the class of work being done and the size of the plant. For example: the gang boss and speed boss are one and the same in some machine shops where work is just sufficient to keep one man busy, but not so busy that part of his duties are neglected.

Under this law comes also the question of a bonus which, as previously stated, is given to workmen to insure that in-

structions are carried out and the quality of the finished product is up to the standard, or, in other words, that the workman is delivering the amount and quality of labor that the management is paying for. Bonuses will not be here discussed, as anyone desiring information on the subject can easily consult Emerson, Gantt, Taylor or Day.

LAW VI.

It is necessary in any activity to keep definite, reliable records of costs, and to be able frequently to summarize costs.

This law hardly needs an explanation, as it is self evident. In order to simplify the cost keeping, reports should be constantly going to the cost department as material for each operation is issued and as each operation is finished, so that on any day the cost data on work going through the shop are complete. The only way in which the management can form an idea of the business is by summarizing cost frequently.

If we neglect to keep a definite and reliable record of costs we will have no knowledge of how we can sell, or if we are turning out work at the maximum efficiency.

As the application of this law covers cost, which is a separate subject in itself, it will not be gone into further than to state that the cost clerk should constantly receive information as to the apportionment of material to a given job, and the labor reduced to cost performed on each operation of a given job, when the operation is completed. His data should be so complete that at the end of each month he can apportion costs to each job and determine the cost of manufacture of all finished products.

His notice that a job is to be done may be the receiving of the manufacturing order, and that the job has been started in the shop, the receipt of the "tickler" (carbon copy of manufacturing order) from the production clerk. From this time until the order is shipped he receives records of all costs covering that order, as material is issued for each operation and as work is finished on each operation. The *method* of giving him this notice need not necessarily be the one here suggested.

A further application of complete costs records is in the estimating of new work, or work that is not standard. The operation of this law should make it possible to reduce the difference between estimated and actual costs of work to 2 per cent.

LAW VII.

It is necessary in any form of activity for those directing the work to study for improvements of (a) *costs,* (b) *methods,* (c) *machines and tools,* (d) *product,* (e) *labor.*

In order to improve conditions as given under this law it is best to have an expert with assistants to study each detail. While improvements will often come from men who are carrying on the planning of the work and the work itself, it is better to have some one who devotes his entire time to the subject of improvements and who will examine into and act on any recommendations that come from the men either in the management or in the shop.

In studying labor the aim is to so treat the workman that he is satisfied and knows he is getting a square deal at all times. This is one of the most important functions of Law VII, and will result in decreasing the losses due to men quitting work or striking or loafing because they are disgruntled with the management.

Not to study improvements in costs, methods, machines, tools and product will result in so antiquating any business as to place it at the mercy of its competitors, due to loss of time in manufacture, loss of business through inability to reduce costs to meet competition, and loss due to decreased sales resulting from the poor quality of the finished product.

To ignore the study of labor and to disregard all its demands, almost its existence, except in so far as it helps to make money, is almost the same as business suicide. The concern that does this or allows it to be done will have strikes, discontented workmen and poor workmen, with large losses due to idleness of the machines.

The application of Law VII should be as follows: The improvement department will be directly under the general man-

ager or general superintendent. Although the last law, it is one of the most important in that it deals with labor. Before discusing this function it must be stated that methods in the planning department and in the shop should be constantly studied for improvement. One method of doing this in some industries would be to make time studies. The machines and tools should be studied, and where changes can be made for improvement they should be made, having regard to interruption of the work. Finally the finished product should be studied in order to improve it; for example: by cutting out or simplifying parts, by improving the usefulness of the machine in performing its function, and, finally, by increasing the field of usefulness for the machine. This law will cover, for further example in some branches of industry, studying methods for utilizing waste products, as by treating them so that they can be cheaply turned into saleable products, and to find uses for these products.

Finally, labor should be studied to *prevent antagonism of labor to capital* by giving labor fair and square treatment. This object should be carried out by a department in charge of a man of greatest tact and diplomacy which should have charge of:

(1) Employing and discharging labor.

(2) Distributing labor throughout the plant.

(3) Disciplining men for violations of rules and regulations. Rules and regulations should include punishments for various standard offences, such as loafing, drunkenness, insubordination, etc. The punishments should be uniformly enforced. In a large plant this will necessitate maintaining a police department.

(4) Keeping records of all labor employed, with the past history of each man, if it is possible to obtain it.

(5) Paying labor.

(6) The benefit fund.

(7) Washrooms, lunch rooms, etc.

(8) Library and any other "uplift" ideas that are in operation.

(9) Recommending devices and methods for preventing loss of life and property. This would necessitate in a large plant a fire department.

(10) Intercourse with the men through their representatives to discuss questions concerning labor at certain stated times.

(11) Adjusting differences between workmen, or between workmen and bosses.

(12) Distributing men to reduce friction between them and to reduce as much as possible partiality on the part of the bosses.

(13) Medical attendance on men who receive injuries in the shops. In a large plant this would necessitate a hospital.

(14) Improving conditions in the shops so as to reduce strain on the workmen, such as ventilation, heating and lighting.

The Illinois Steel Company at South Chicago has a labor department that is a model of its kind, and should be copied by every large industrial concern in the country. Its adoption will undoubtedly result in the elimination of friction between capital and labor. The author has talked with managers of concerns where labor troubles are practically unknown, and in every case this last law was found to be carefully observed. On the other hand, where there is a total disregard of conditions from the standpoint of labor—in other words, where labor is not studied—strikes are frequent and, strange to say, are looked upon as necessary evils. In these shops, also, it will generally be found that the average quality of labor is very low, good men leave such places to go where they are better treated and where they are not thrown out of work through strikes and walkouts. These are usually caused by a blind desire on the part of the management to make money at any cost, in many cases on a highly watered capital, the dollar sign being the *only* thing on the horizon of the board of directors and the management.

There is one point in management that is very often lost sight of; that is, that two objects should not be stated as one

in applying the laws of management. For example: If we stated the object as being the manufacture and sale of certain machines, confusion would immediately result. The manufacture of machines is a distinct and separate operation from the selling of machines, and each should be treated separately in applying the laws of management. Due regard should be given to the fact that the connecting link between the two is the exchange of information between them as to costs, rate of output, capacity of the manufacturing department, the number of sales, dates of delivery, capacity and size and character of the finished product, and new contracts as they are made.

To illustrate this more concretely, the company supplying electric current and gas to a large city performs several functions. Taking only the electric part of it, there are the manufacture of current, the selling of it, the buying and installing of motors, wires, lights, etc. These functions are so confused that it is often difficult for the manufacturing department to know exactly on what days the installing department will finish its work, consequently the selling department has difficulty in promising the delivery of the current. The proper way under the laws of management to conduct this business is to separate each function from the other and to apply all the laws of management to each, providing means for exchanging necessary information between the departments. Thus the functions would be separated into (1) manufacture, (2) selling, (3) installing; each being conducted separately from the other except in the exchange of necessary information.

The criticism has been made that Law VII conflicts with Laws III and IV in that the last two laws require that the best tools, machines and men have been selected for the purpose and eliminates the necessity for studying for improvements. There is no question that the best tools, machines and men may be selected this year, yet five years from now such improvements may have been made as would put a company out of business if it had not constantly studied for improvements and applied them as they are discovered. If the men are not improved by constant study and instruction, then human na-

ture is not what it is accepted as being. The mere fact, though, that the most successful manufacturers are studying for improvement in machines and tools, and in labor, is proof of the existence of this seventh law of management, and that it does not conflict with Laws III and IV.

It has been said that it is time to stop talking of principles and to begin to show the application of them and the final outcome. The author claims that principles and laws have not been discussed before, but that *methods,* under guise of principles, fundamental principles, laws, and other names not belonging to them have been discussed. This paper for the first time records the laws of the science of management and gives a starting point to those who wish to discuss methods. As to the results obtained by this application, it can be said that to record them would be as big an undertaking as to record the methods of carrying out the laws. If the laws of management are carefully observed the results will be success—success as nearly perfect as can be obtained by human methods working with human beings.

Again the criticism is made that Law II will not apply to the inventor, or to the man engaged in scientific research; that the very fact that a purpose is formed to make a discovery, invention, or improvement presupposes that what is to be done and final results are unknown. The mere stating of the purpose, recording it on the brain or on paper, forms instructions as to what is to be done. Whether the invention is a mechanical one, or whether the discovery is a chemical one, in either case the inventor or discoverer must know the laws of mechanics or the laws of chemistry in order to obtain the most successful results. That the final result is known approximately must be granted, or the discoverer or inventor is working without a purpose. That the laws do apply to accidental discovery is not contended, but it is contended that, whether in invention or in scientific research, the *greatest degree of success* will be obtained by the person who applies the laws of management.

That Law II is too broadly stated in that it does away with all initiative on the part of the individual workman is another

criticism that is made. The answer to this is left to the large number of successful employers engaged in productive work who require that the laborer carry out orders, and who do not give him a wide latitude in which to experiment on his employer's material and probably ruin it. It must be granted that the management knows what it wants done and how it wants it done, and that the work should be done according to its orders.

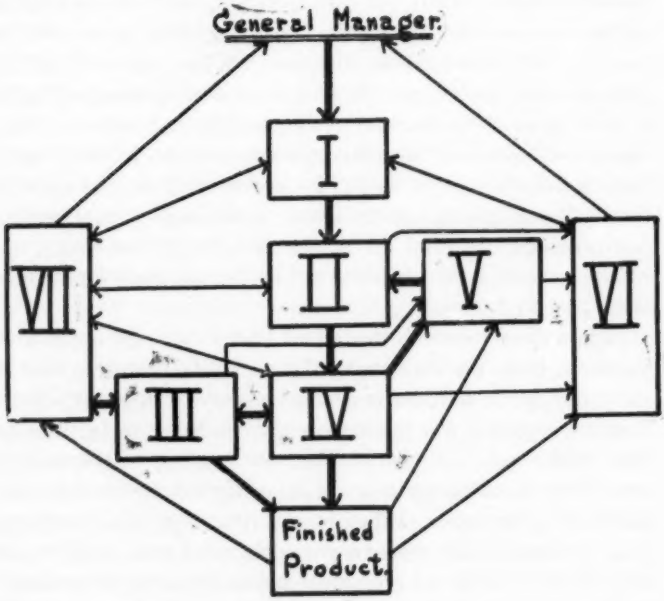


Figure I.

A reduction of the seven laws of management to diagrammatic form is shown in Fig. 1. This shows the simplest form of their application to any activity. The work progresses from the general manager to the estimating and drawing room (covered by Law I), to the planning department (covered by Law II), to the shop (covered by Laws III and IV). Law V

is a connecting link between shop and planning department. Costs and improvements keep in touch with all (covered by Laws VI and VII).

In Fig. 2 the different elements are given their proper names. The planning department is placed within the shop, as it is in reality a part of the shop. In large plants such as the Allis-Chalmers Co., for example, each shop has its own planning department, while in a smaller shop such as the Tabor

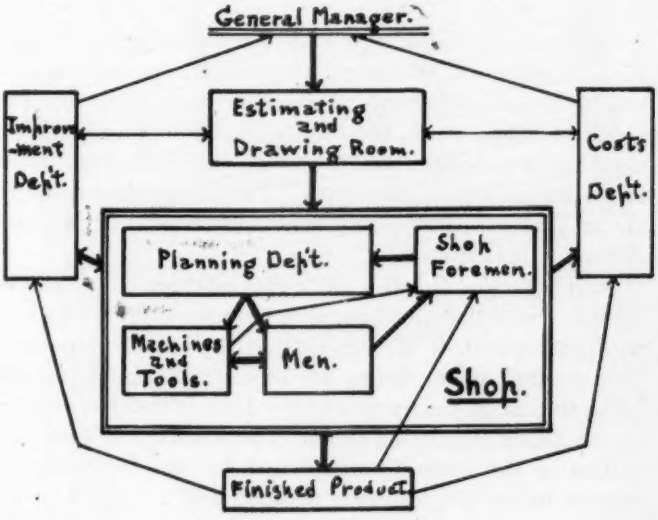


Figure II.

Manufacturing Co., there is one planning department for a shop employing about ninety men. The number of men requiring a separate planning department can only be determined by the size and nature of the industry and the arrangement of the plant. The Bement-Miles Works of the Niles-Bement Pond Co., for instance, has one planning department for about fifteen hundred men, and successful results are obtained.

THE CONVERSION OF NICLAUSSE INTO BABCOCK & WILCOX BOILERS ON THE U. S. S. *COLORADO* AND *PENNSYLVANIA*.

By Commander C. N. Offley, U. S. Navy, Member.

Owing to the high cost and the difficulty of obtaining spare headers and other pressure parts for the renewal, from time to time, of defective and worn-out parts of the Niclausse boilers on these ships, the Bureau of Steam Engineering decided to convert eight boilers on each ship from the Niclausse to the Babcock & Wilcox type. The old headers and tubes are to be retained in stock as spares for the remaining Niclausse boilers.

Drawings Nos. 1 and 2 show the arrangement of the new boilers; No. 1 showing in broken lines the original Niclausse with the new B. & W. elements in their relative positions. The original steam drums are retained, a reinforcing strap being riveted on the outside of the drum in wake of the holes for the 4-inch circulating tubes. The double-cone joint at the bottom of the drum formerly used for the down-take connection to the old header is retained and a flanged plate is used to take the place of the top of the old header. The upper end of a bent down-take nipple is rolled into this plate, the other end of the nipple being expanded into the back of the new header near its upper end.

Referring to drawing No. 2, it is seen that the dogs and their nuts of the lower back hand-hole covers appear in contact, and before the work was started a question was raised as to the accessibility of these for setting up, and for rolling in the back ends of the lower tubes. In actually setting up the work, however, it was found possible to separate the back headers a little more than the drawing shows, and it should

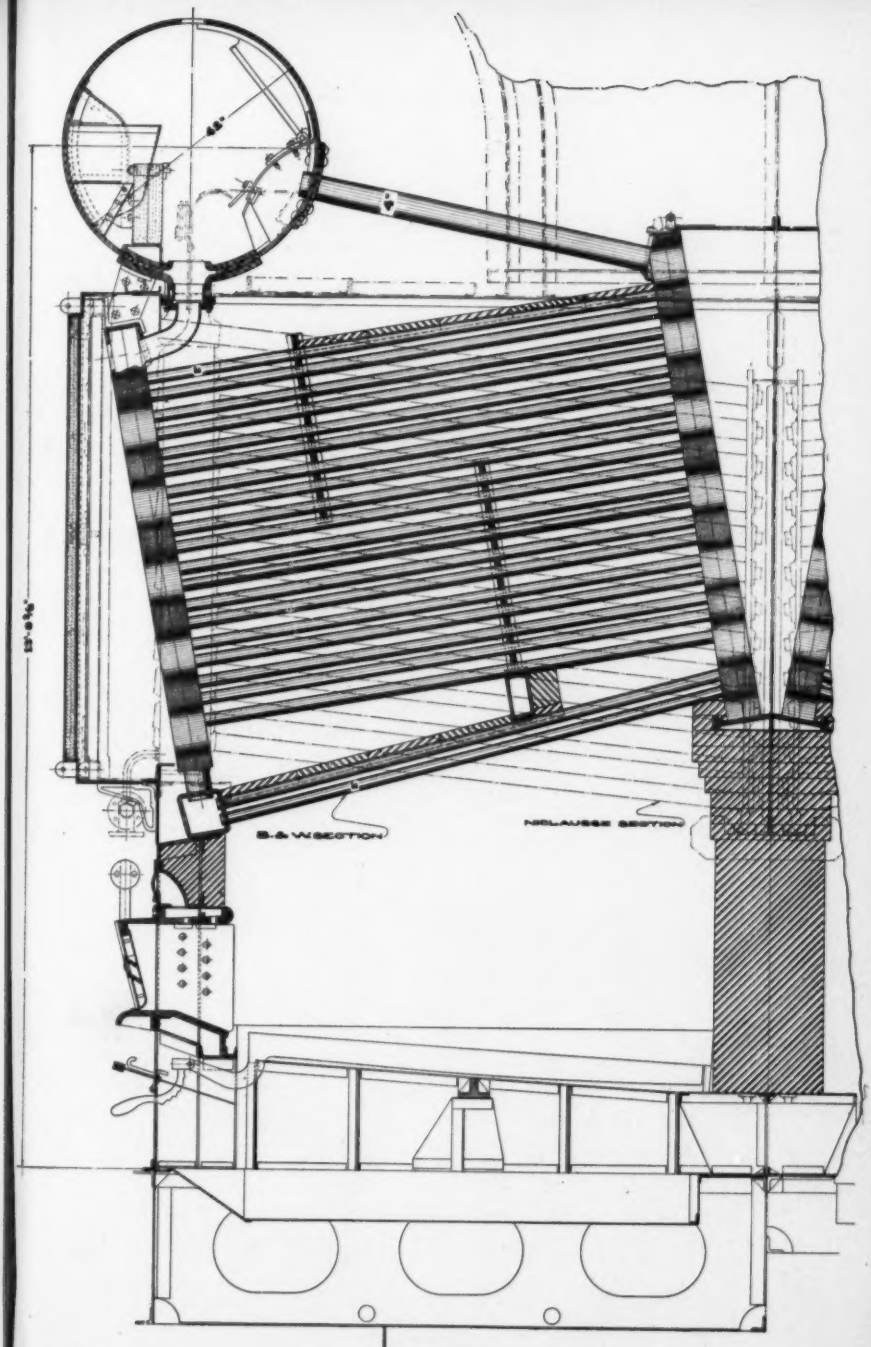


Fig. 1.

also be noted that the headers in the opposite boilers are slightly staggered. No difficulty was actually found in erecting, and the back ends of the lower tubes were easily rolled in, using a knuckle joint on the mandrel of the expander.

One adverse criticism that has weight has been made, viz: in case of the blowing out of one hand-hole gasket in any of the four boilers on one side of the ship it will be necessary to haul fires in all four before a new gasket could be fitted.

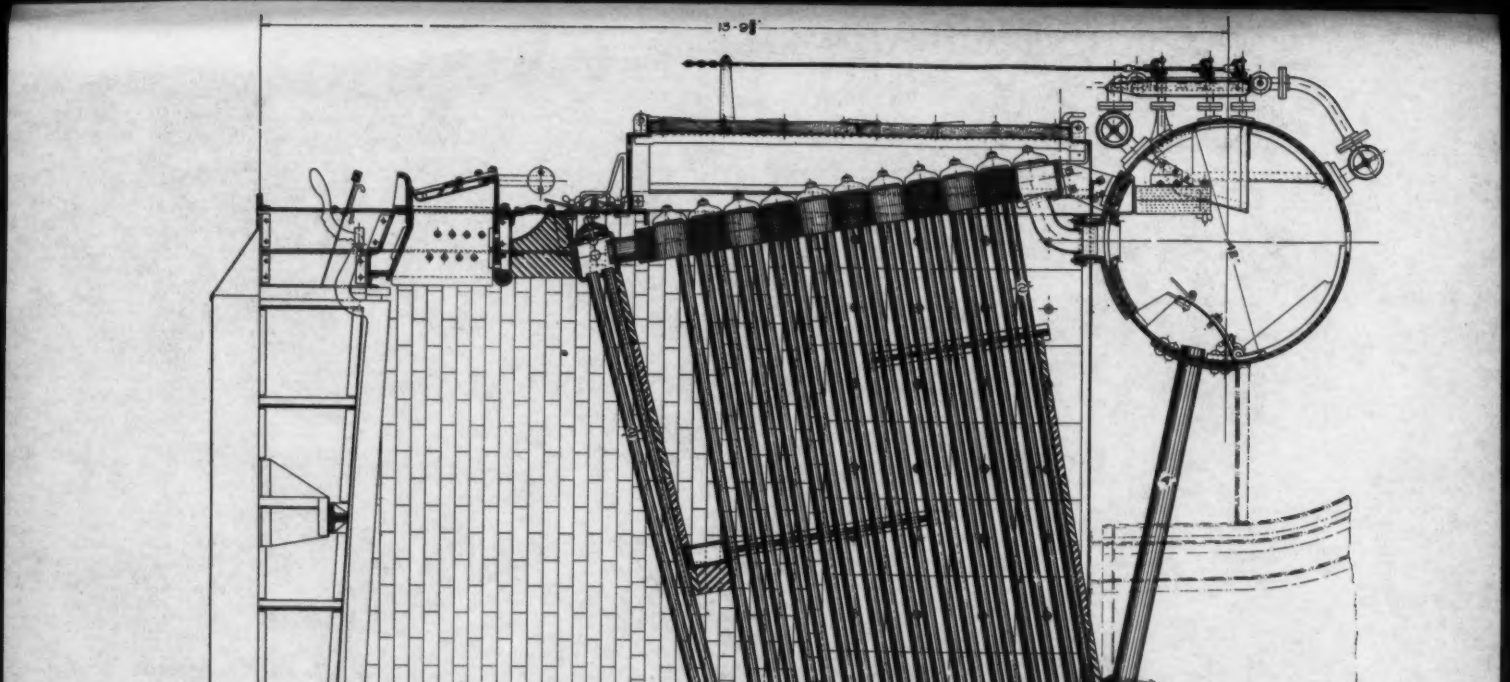
The question of sweeping the fire sides of the tubes arose early in the course of the work. On account of the small space between the outboard boilers and the bunker bulkheads it was impossible to install the usual dusting doors in the boiler casings. Therefore, the arrangement shown by drawing No. 3 was worked out and installed in all boilers of the *Colorado*. On the *Pennsylvania* this will be installed in the outboard boilers only, and the usual B. & W. dusting doors will be used for the inboard boilers.

The actual conversion of the boiler parts involved but a comparatively small amount of the work as a whole, since it was necessary to cut away and remove all of the uptakes and a portion of the lower part of the smoke pipe in order to remove the drums to the shop for riveting and drilling for the circulating tubes. This might have been done on board ship, but as the inner-bottom plating under the *Colorado's* boilers was in bad condition, it was decided to renew this at the same time, so it was deemed more economical, on the whole, to take the drums to the shop.

The old elements were removed intact without drawing the tubes from the headers, and the new elements were delivered to the yard with the tubes already expanded in the headers, except the lower generating tubes. It will be noted from the drawings that there are no 4-inch generating tubes.

A point of interest is that the new headers have no welded longitudinal seams, being somewhat similar in this respect to a solid-drawn seamless tube with the ends welded in.

Drawings Nos. 1 and 2 were kindly prepared and furnished for this article by the Babcock & Wilcox Company.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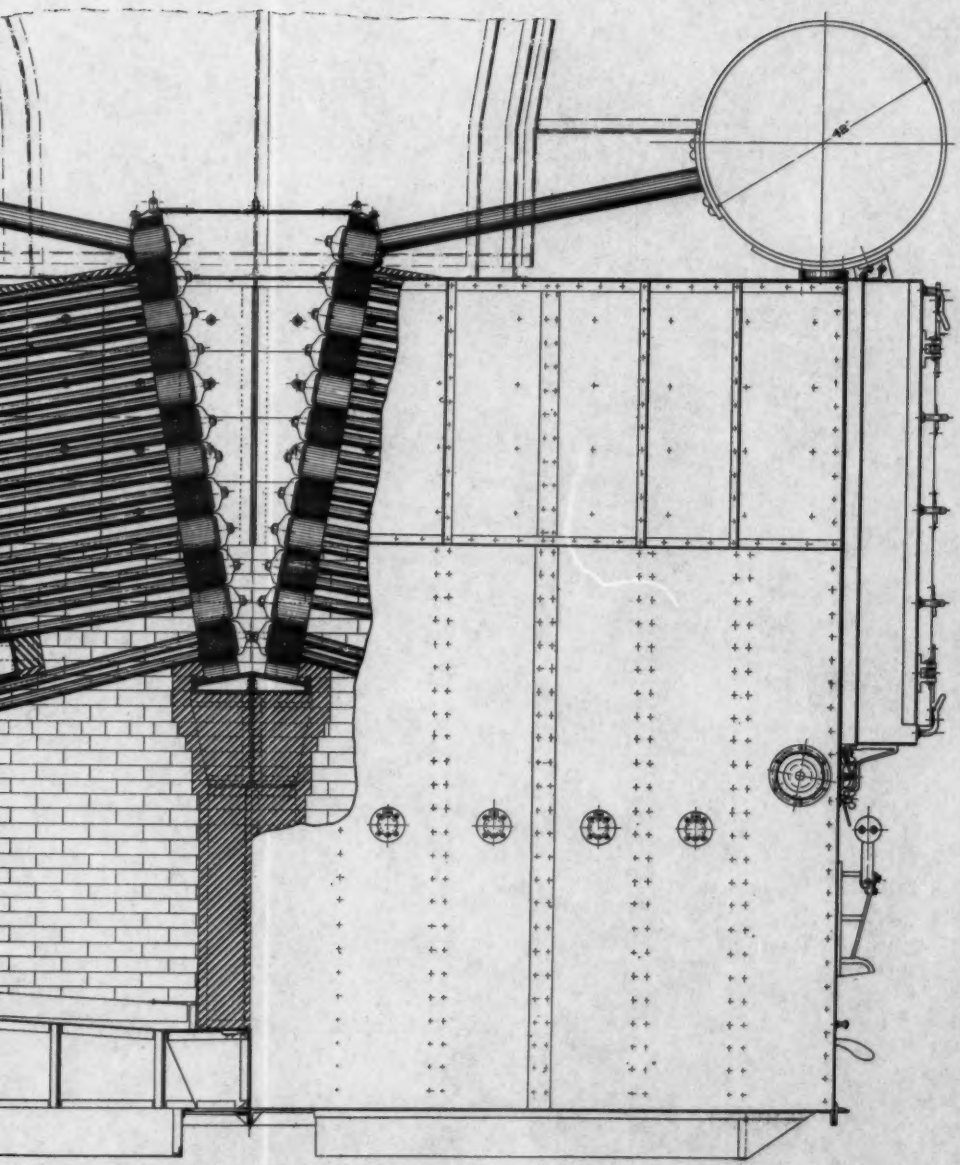


Fig. 2.

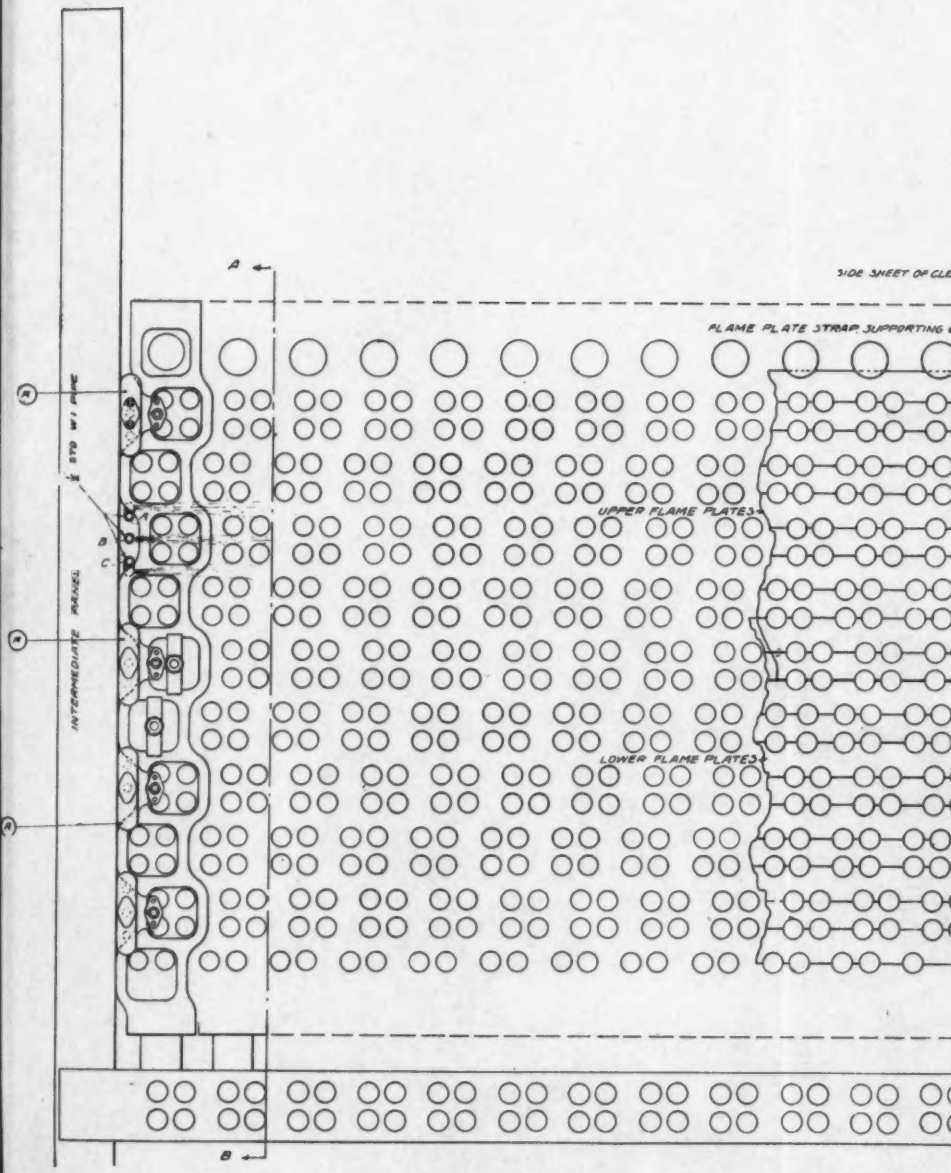
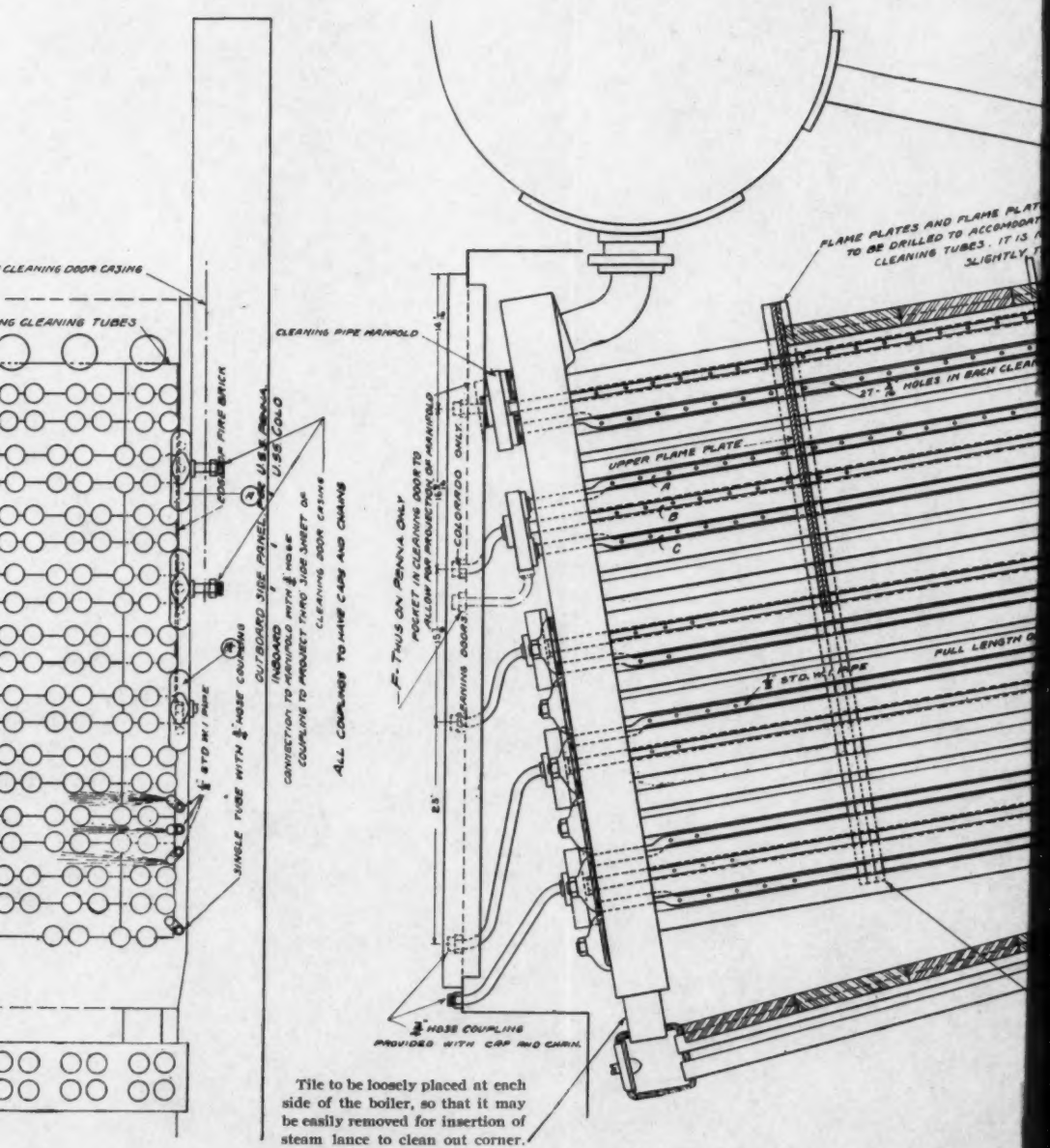


Fig. 3.—This Installation for Intermediate an



Tile to be loosely placed at each side of the boiler, so that it may be easily removed for insertion of steam lance to clean out corner.

AND INBOARD SIDE PANELS ON U. S. S. "COLORADO," AND FOR OUTBOARD SIDE PANELS U. S. S. "PENNSYLVA

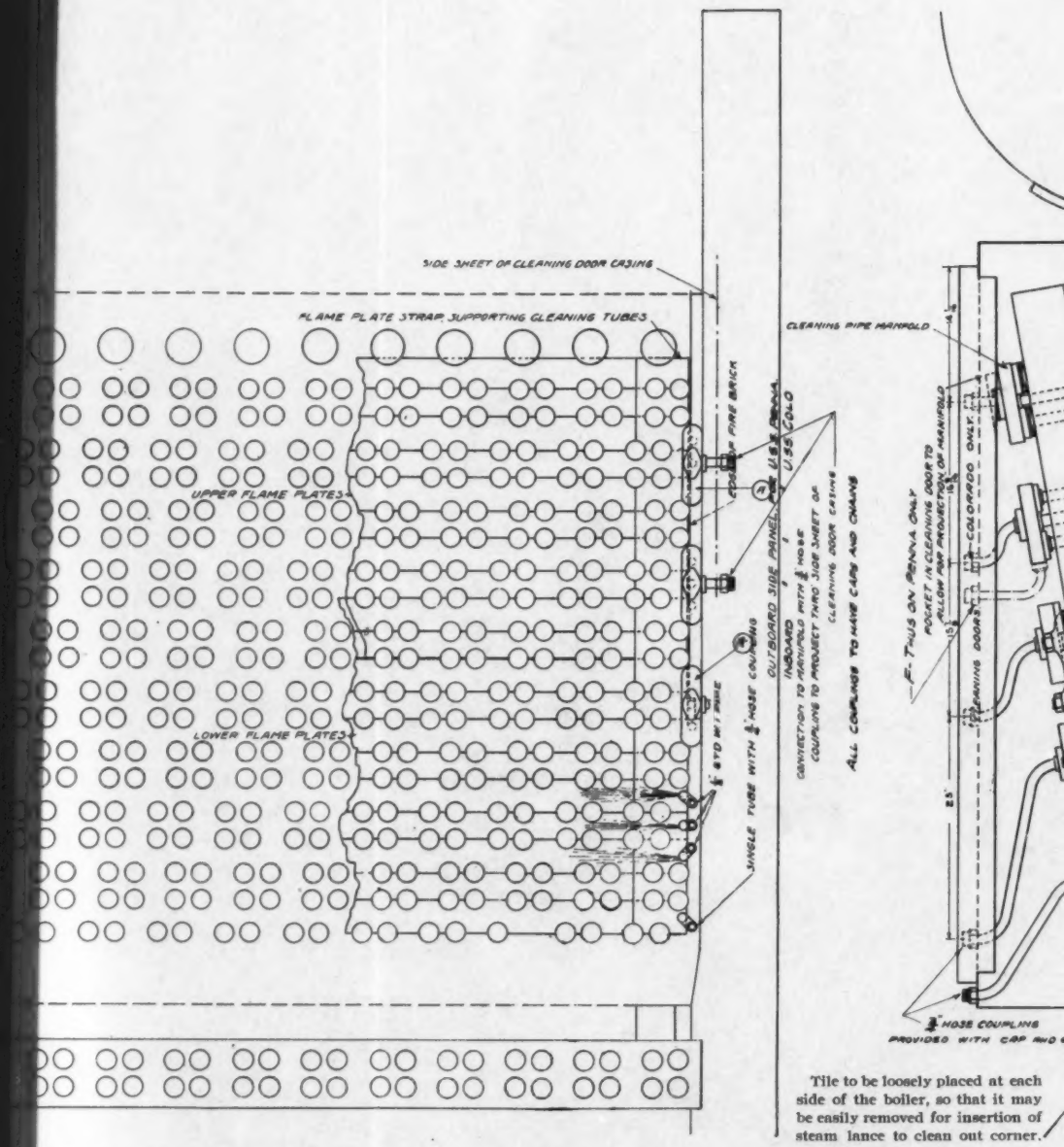
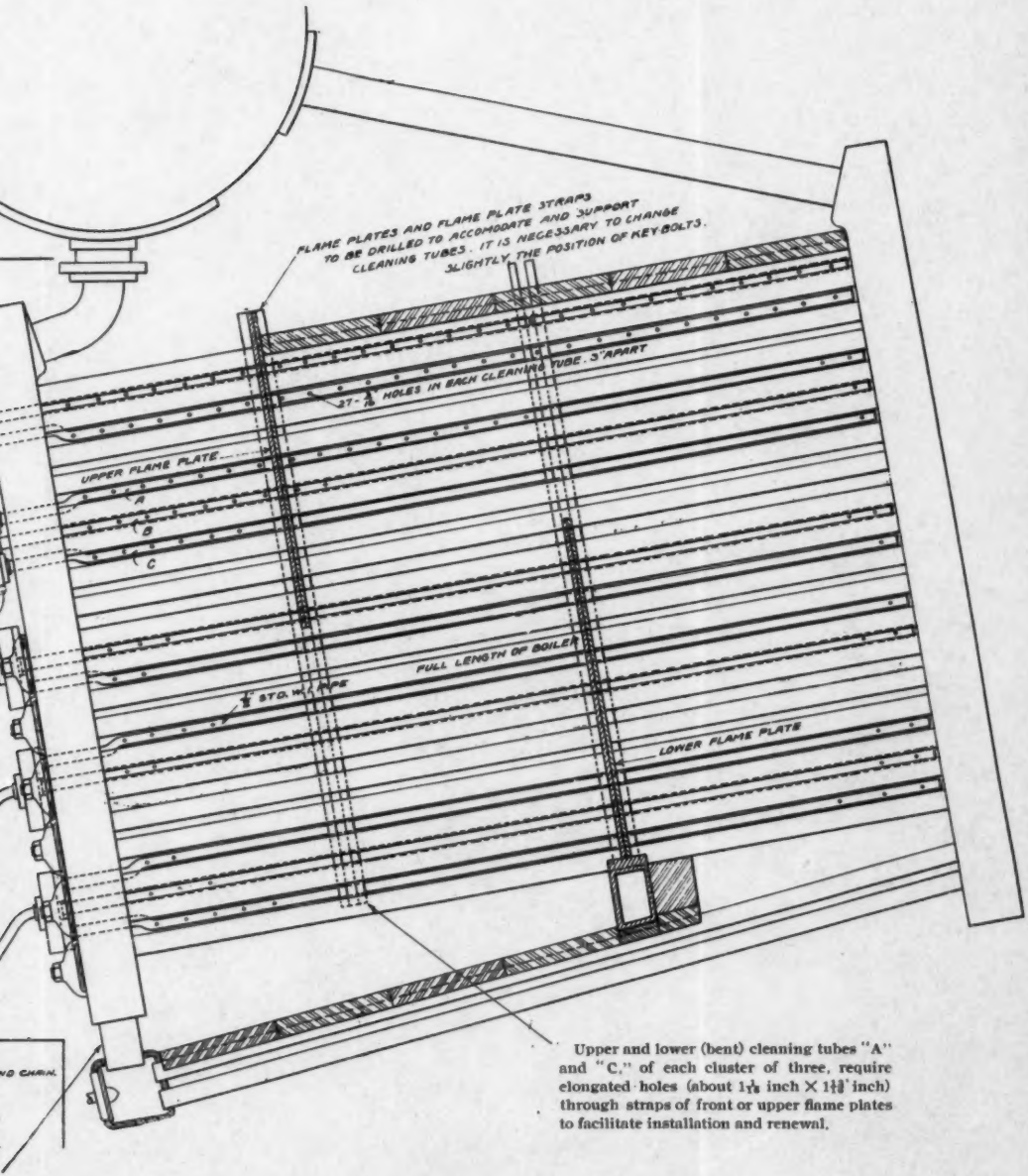

SIDE SHEET OF CLEANING DOOR CASING
FLAME PLATE STRAP SUPPORTING CLEANING TUBES
UPPER FLAME PLATES
LOWER FLAME PLATES
SINGLE TUBE WITH ¾" HOSE COUPLING
CLEANING PIPE MANIFOLD
OUTBOARD SIDE PANEL
INBOARD WITH ¾" HOSE COUPLING TO PROJECT THRO SIDE SHEET OF CLEANING DOOR CASING
ALL COUPLINGS TO HAVE CAPS AND CHAINS
F. THUS ON PENN'A ONLY
POCKET IN CLEANING DOOR TO ALLOW FOR PROJECTION OF MANIFOLD
COLORADO ONLY
CLEANING DOOR
¾" HOSE COUPLING
PROVIDED WITH CAP AND
Tile to be loosely placed at each side of the boiler, so that it may be easily removed for insertion of steam lance to clean out corner.

Fig. 3.—This Installation for Intermediate and Inboard Side Panels on U. S. S. "Colorado," and


FLAME PLATES AND FLAME PLATE STRAPS TO BE DRILLED TO ACCOMODATE AND SUPPORT CLEANING TUBES. IT IS NECESSARY TO CHANGE SLIGHTLY THE POSITION OF KEY BOLTS.
27-13/16 HOLES IN EACH CLEANING TUBE. 3" APART
UPPER FLAME PLATE
A
B
C
FULL LENGTH OF BOILER
LOWER FLAME PLATE

Upper and lower (bent) cleaning tubes "A" and "C," of each cluster of three, require elongated holes (about $1\frac{1}{8}$ inch × $1\frac{13}{16}$ inch) through straps of front or upper flame plates to facilitate installation and renewal.

D FOR OUTBOARD SIDE PANELS U. S. S. "PENNSYLVANIA."

LARGE-MOTOR VESSELS.

By Prof. W. Laas, Charlottenburg.

Read at the III Deutscher Seeschiffahrtstag, Berlin, March 21, 1911.

For the shipbuilder and for the whole shipping trade the large-motor vessel question is by far the most momentous one of the day; its importance is as great as was that of the introduction of steam power some one hundred years ago, the only difference being that technical improvements now make their way much more rapidly than they did a century ago.

Chief among the many new departures in ship propulsion which the last decade has brought us have been the water-tube boiler, the turbine, and superheated steam. Of these only the last named has established itself in the merchant services, the two others being almost entirely confined to war vessels, and here and there only applied to fast passenger vessels. In contrast with these conditions the large motors will in the first line appeal to the merchant service, although the increase of power which they bring will be of great value to war vessels also.

The stage of development now reached is such that we must give our serious attention to the question, Will the propulsion of ships in the near future or within a measurable time be effected wholly or for the most part by means of oil motors instead of by coal and steam? The economical importance of this question may best be made clear by means of figures. Statistics of the total horsepower now in existence in merchant vesels do not exist, only the annual returns of individual countries in some cases giving the indicated horsepower totals of recent years along with those of the gross register tonnage. From these latter returns it appears that for every 10 gross register tons about 8 horsepower has in recent years been

turned out. If a proportion of about 10 to 6 be taken for the whole of the merchant steamer fleets of the world, the engine equipments of the latter will work out at six-tenths of the 37 million gross register tons given by Lloyd's Register, or in round numbers at 22 millions of indicated horsepower. The naval fleets of the world are credited in the various statistical compilations with indicated horsepower totalling up to 15 millions. For the first cost of the engines of merchant steamers £7–10–0 per I.H.P. may be taken as a low estimate, about £2-10-0 going to the shafting and to the auxiliary engines and £5–0–0 to the main engines and boilers. The corresponding values for war vessels must be placed higher, so that the total value of the main engines and boilers of seagoing vessels of all kinds amounts in round numbers to 200 million pounds, which may within measurable time be for the most part rendered worthless by the advent of the oil motors.

A shifting of values of this revolutionary character can be brought about only by very considerable advantages attaching to the new mode of propulsion. In what, then, do the great disadvantages of the propulsion by the steam engine lie? From the point of view of the shipowner and the merchant the disadvantages are not so very great. For commercial purposes the ship is only a means to an end—for the shipowner, the engine is only a necessary evil, and the less he hears of it the better he is pleased. For ocean commerce the steam engine fulfils its purpose; it has attained a high degree of reliability, and supplies of coal for it are obtainable at all important towns of the world. In general, then, the position is justified which I have found many managers of shipowning companies take up, that they are not by any means pleased at the prospect of the so-called " improvements " which, in the keen competition of the period of transition, will bring a series of very disturbing alterations in their train.

As has so often been the case in recent times, the movement has been set on foot by the engineers, who are constantly striving after the economically better. The disadvantages of pro-

pulsion by the steam engine are of a general character and lie in the complicated indirect development of power, in which large losses occur by reason of the generation of the steam in the boilers. The endeavors of the engineer, from which the motors have sprung, are directed towards the abolition of this intermediate member and the direct development of power at the point where it is required, namely in the engine itself.

What are the advantages which thereby accrue *to navigation?* The abolition of the boilers will be hailed with delight not only by the seagoing and superintending engineers, but also by the captains and owners. The boilers constitute a constant source of cares and dangers, and require large staffs for their working, the obtaining and management of which are beset with increasing difficulties. Even in the case of an ordinary merchant steamer, the allowances of weight and space for the boilers are considerable, while in large passenger liners and war vessels they increase to such an extent as to determine the sizes of the vessels or the speeds of these on given dimensions. The sole reason why the *Mauretania* had to be so much larger than the fast liners of the North German Lloyd was that the large horsepower necessary for the attainment of 25½ knots in place of the 23½ knots of a vessel of the size of the *Kaiser Wilhelm II* entailed an amount of boiler space which could not be obtained otherwise. In addition to the space and weight thus required comes the supply of fuel. As a result of the indirect development of power by the boilers, the average consumption of coal in the best steam installations is still at least 1.3 to 1.55 pounds per I.H.P. per hour, that in the oil motor with its direct production of power being only about one-third as much.

The great advantages of the motor propulsion as compared with that by the steam engine are, then, the following: Great saving of space and weight in consequence of the abolition of the boilers and of the reduction of the consumption of fuel to one-third. With this comes the elimination of a large proportion of the stoker contingent. A large number of designs

which, with the coöperation of the shipowners, have been got out during the last few months for some of the principal types of merchant vessels, have given the following general results:

Compared with a steamer, a motor merchant vessel in the European coasting trade saves about 10 per cent. in space and weight; in the long-voyage trades, such as those to South America or the Black Sea, the saving ranges up to 20 per cent.

A high-seas fishing vessel with a motor can take fuel with her for twice the time that a steamer can, and in addition can make room for about 50 per cent. more fish.

The most marked differences, however, are shown by fast passenger liners. A vessel of the size of the *Kaiser Wilhelm II* can take in a motor installation of 60,000 I.H.P. in place of the 40,000 I.H.P. now carried, and will thereby attain a greater speed than the much larger *Mauretania;* at the same time she can take in sufficient oil in New York for the journey out and home, while under present conditions she has to coal both in Bremerhaven and in New York. Meanwhile, in spite of the 50 per cent. increase of power and the 100 per cent. increase of radius-of-action a considerable saving in weight is effected and the draught is thereby reduced.

Similar results are shown by war vessels, which cannot, however, be further gone into here.

The advantages thus enumerated are so surprisingly great for almost all vessels that the end in view appears worthy of some effort; the only question is, whether we are today so far advanced that installations of this character can be reliably carried out.

Here there are a series of difficulties to be surmounted. The most important of these is to be found in *the motors* themselves. As matters stand at present, only the oil motors come in question for use on shipboard. Gas motors fall away, because the carrying of gas or its generation on board requires as much or more space and weight as a boiler installation. Of the oil motors, again, only those can be considered for ship use which burn the less valuable parts of petroleum, that is to say, practically those on the Diesel principle.

The single-acting *Diesel principle* works in the following manner: Pure air, which is introduced into the cylinder, is compressed by the backwards-moving piston to about 30–35 atmospheres (first stroke); during this compression the air becomes so hot that at the end of the stroke injected oil burns uniformly, this occurring while the piston is moving forwards (second stroke) with an approximately constant pressure (uniform pressure method). The combustion is followed during the second stroke by expansion and then by exhaust, as in the steam engine, with the addition, however, which is unknown to the latter, of the scavenging and the reception of fresh, pure air, which then has to be compressed again as first stage in the repetition of the process above described. In the two-cycle arrangement the scavenging and the heating of the air take place at the end of the "second stroke" and at the beginning of the following "first stroke." In the four-cycle motor the scavenging takes place during a third stroke, and the drawing in of pure air during a fourth, and only then does the next cycle begin with another first (compression) stroke. It will be seen from this description of the process that there are the following characteristic differences between the steam engine and the single-acting motor:

The steam engine is double-acting. The upper and lower parts of the cylinder work alternately in one and the same manner. At each revolution each piston does two strokes of work; that is to say, it twice experiences steam supply and expansion—once from above and once from below. The single-acting two-cycle motor has only one working stroke per revolution and the four-cycle engine only one working stroke per two revolutions.

To enable it to work properly the marine screw propeller needs a uniform turning moment. For this reason and on account of the reversing, the three-cylinder arrangement is almost universally adopted for the marine steam engine. If equally uniform turning moments are to be attained (without

flywheels, which come in question only for small installations) with motors, six two-cycle or twelve four-cycle cylinders have to be adopted.

From this it is clear that the two-cycle system has the advantage for large marine engines, even though the disadvantage attaches to it that it requires special air pumps for the scavenging and filling processes, while in the four-cycle motor the main cylinder acts as an air pump during the third and fourth strokes. Further, the endeavors to make the two-cycle motor double-acting, and thus more like the steam engine, may readily be understood. It is not desirable, however, to go too far in this direction; in shipping circles it is sometimes extolled as a special advantage of some one of these systems that the motor works "exactly like a steam engine." Shortsightedness of this kind cannot be resolutely enough encountered.

The manners of working of the steam engine and of the motor are fundamentally different. What a large boiler in continuous work supplies to the steam engine the motor has itself to provide in the shortest of time in a small part of its cylinder. This may best be illustrated by an example. A steam engine of 1,000 I.H.P. requires a marine boiler with about 2,700 square feet of heating surface, a diameter of 15 feet 9 inches, a length of 11 feet 10 inches, and a capacity of about 2,300 cubic feet. The combustion spaces in the motor, which correspond with this boiler, contain only about 11 gallons. The power which the boiler supplies to the steam engine has to be produced every time in this small space in about one-twentieth of a second by combustion under high pressure and at high temperatures. The important point in a motor, then, is not that it looks and works like a steam engine, but that it has a combustion chamber of the simplest possible description that can be thoroughly scavenged. This gives reliability in working, even at slow speed, and also quick starting, good maneuvering qualities, and small consumption of oil, in fact the main qualities which must be demanded of a marine engine.

Further requirements for the reliability in working of the oil motor are good cooling and lubrication of the piston. In the motor with its high temperatures these important conditions accord badly with the working of the piston in a closed cylinder as in the steam engine; with the high pressures of the motors, also, the difficulties of packing the stuffing boxes, which are still well under command in the steam engine, become increasingly important.

No final verdict can yet be given on the *various systems of marine motors;* experience only can decide between these. It is a very satisfactory circumstance, therefore, that a large number of shipyards and works are applying themselves to the problem of the production of a large oil motor for ships. Apart from the standard Diesel design the systems competing in Germany are those of the Krupp-Germaniawerft-Kiel, the Augsburg-Nürnberg Engine Works, Junkers of Aachen, Carels of Ghent, and Sulzer of Winterthur. To these must be added a series of firms in Germany which also build motors for marine purposes, but which have hitherto confined themselves to smaller installations or to engines for special vessels such as submarine boats. Of large-sized marine motors there are at the present time (March 21, 1911) to my knowledge seven installations to different systems, ranging from 800 to 1,800 E.H.P. per shaft, under construction in Germany, and a series of negotiations are in progress for the construction of motor vessels. Further, large experimental motors of from 1,000 to 2,000 E.H.P. per single or per double cylinder are being designed, built or tried in Germany and abroad. As soon as these installations have been put to the test, it will be possible to supply oil motors of 10,000 H.P. or more per shaft; the advance to the largest powers required for war vessels and fast liners will come of itself. Difficulties of various kinds will, indeed, show themselves in connection with the large installations, but it may confidently be expected that they will be surmounted. The first preliminary requirement for motor vessels—serviceable motors of large size—is thus al-

ready fulfilled as regards the largest merchant vessels. In addition to these, however, there still remain a series of important points to be decided, namely, the driving of the auxiliary machinery, the stowage of the oil, the cost of the motors, the cost and supply of the fuel, the personnel and the position to be taken up by the port authorities and the insurance companies. These points may now be discussed in succession.

For the *driving of the auxiliary engines* there are three possibilities:

1. The steam-motive machinery may be retained for pumps, steering gear, windlasses and winches; this requires the presence of a donkey-boiler installation, by which a part of the advantages of the motor as regards weight and space is taken away again.

2. The auxiliary machinery may be driven with compressed air, which must in any case be present for the working of the main motor. The disadvantages of this method of driving are the ice formations on the cylinders which result from cooling due to the expansion of the compressed air. This disadvantage can be avoided by the warming of the feed of the compressed air, perhaps with exhaust gas; the heating of the cabin accommodation may also be effected from a reservoir, into which the exhaust gas can be led.

3. The auxiliary work may be done by electric power which is already present on the larger vessels for the lighting installation. Disadvantages of this motive power are its high first cost and the circumstance that the winches would have to be driven by men inexperienced in their use.

For cargo vessels a combination of the three possibilities is, in the meantime, probably the best, that is to say, electric power for the pumps, heated compressed air for the steering engine at sea, and steam supplied by a donkey boiler for the latter as well as for the winches and windlass in port. For passenger vessels, with their large crews, the electric drive will, in view of the long leads and of the avoidance of noise, in all probability be the best.

The storing of the oil is not quite such a simple matter as that of the coal, because of the difficulty of keeping riveted tanks tight. In this particular, however, sufficient experience has been obtained with the petroleum tank steamers; it does not seem desirable, however, to arrange the oil supply exclusively in the double bottom or in tanks adjacent to the skin of the vessel, since groundings or blows received from piers may easily produce leakage. In every case there must be a good supply of fuel in special tanks in the engine room, this being desirable also in view of the tonnage measurement, which will be considered further on.

The *cost of the motor vessels* is higher than that of steamers of equal size, and for large installations may at the present time be put down at £7–10–0 per E.H.P. for the motor itself; to this, however, come the fitting on board, the shafting and propeller, and the auxiliary engines and apparatus, with perhaps a donkey boiler, so that the total may be assumed to be by about £2-10-0 to £3-0-0 per I.H.P. dearer than that of a steam installation of equal power. For this additional cost, however, the vessel obtains an increase of net carrying capacity of about 10 to 20 per cent., and lower working expenses on account of savings in the personnel. In addition it is to be expected that the prices of motors will become lower.

The *price of the oil* fluctuates within wide limits, somewhat as is the case with coal, according to the distance from the sources of supply. There are districts in which oil may be obtained for from £1-5-0 to £1-10-0 per ton, while in some other important shipping centers it costs twice, or more than twice, these amounts. The price of oil and the obtaining of oil at as many places as possible are the fundamental conditions for a remunerative motor-vessel service, and it is to be hoped that the oil-transport firms on this domain will not first await the advent of the urgent demand, but will pave the way for the extension of the motor-vessel services by the establishment of plenty of oil depots. At the present time coal depots are to be found in every port; oil depots on a somewhat smaller

scale (since a given quantity of oil reaches three times as far as the same quantity of coal), but distributed to much the same extent, will have to be established. True, the first outlay for these is greater than that for coal depots, but the tanks take up considerably less room, and the subsequent working by means of pipe leads and tank lighters is of a very simple nature; moreover the oil during storage and transport maintains its value, while coal always deteriorates in the depot and in transhipment.

The question now arises, whether the *oil production* of the world is sufficiently great to cover a large demand for it for shipping. In the introduction to this treatise the vessels of the merchant services were credited with 22 millions of horsepower and those of the war navies with 15 millions; in view of particulars supplied by large and small shipowning firms and of figures that are available in regard to the coal-consumption of the various navies, it appears that about 50 per cent. of this horsepower in the merchant steamers and 5 per cent. of that of the war vessels is in constant work during the year. With consumptions of 1.54 and about 2 pounds per I.H.P. per hour respectively, this gives a yearly total of about 67 millions of tons for the merchant steamers and 6 millions of tons for the war vessels. If, now, the steam-engine installations on vessels of all kinds be replaced by oil motors, a state of things which will never come to pass, this would give an annual consumption of oil of 25 millions of tons. At the present time the annual production amounts in round numbers to 40 millions of tons; it would thus need to be increased by only 60 per cent. to enable it to suffice for all the shipping in addition to the other purposes to which it is at present applied. That the oil supplies of the earth will be sufficient to last for centuries to come all the investigations hitherto made place beyond a doubt; it is even asserted that the oil supplies of the earth are greater than the coal supplies. The oil is obtainable from a constantly increasing number of sources, is more evenly distributed, can be more conveniently trans-

ported, and has a higher calorific value than coal; in fact it is an ideal fuel for economically working marine motors.

The *question of personnel* presents no difficulty; even if the removal of the boilers be altogether left out of account, the motors require less attention than a triple-expansion steam engine; it is a matter of certainty, then, that the present engineers will rapidly become accustomed to their new duties.

Not so certain is the position of the *harbor authorities* in the matter; motors and their oil are still looked upon as being specially dangerous. This is not, however, the case; with careful handling, they are less dangerous than boilers and coal. There is no open fire connected with the motor; the oil cannot ignite spontaneously, as coal can, and there are also no large quantities of steam stored up to cause explosions and extensive damage when small faults occur in material or attendance, as in the boilers. A certain amount of prejudice will here no doubt have to be got over before the motor vessel is allowed to enter every harbor as freely as do steamers and sailing vessels.

The same holds good for the *insurance companies*. These also will have to convince themselves that a motor vessel is safer than a steamer and that the premiums can be reduced.

The introduction of the motor into high-seas navigation will still require a great deal of work, not only on the part of engineers, but also in the preparing of the nautical circles represented at the German Ocean-Navigation Day for the change. It is beyond all doubt, however, that the great advantages which the motor propulsion possesses for ocean navigation in particular will overcome all difficulties. Today we are already in the middle of the development. It is no longer a question of " who will be bold enough to be first in risking the new departure;" individual shipowning firms must now take care that they are not last. The first in the field reap the advantage, the last only suffer from the expense of the innovation.

There are at present (July, 1911) on order in Germany thirteen large motors for ships, as follows:

Running number.	Kind of vessel.	Motors.			Shipyard.	Owners.
		Number.	Horsepower.	Type.		
1	Cargo vessel.	2	1,000	Augsburg-Nürnberg Engineer. Works, Nürnberg.	Blohm & Voss, Hamburg.	(On own account). Eventually for the Woermann Linie, Hamburg.
2	do.	2	1,500	do.	do.	Hambg.-Amerika Linie, Hamburg. (Will be built after No. 1 has been tried.)
3	Petroleum tank vessel (reconstruct'd steam'r *Excelsior*).	1	1,800	Carels Frères, Ghent.	Reiherstieg Schiffswerfte, Hambrg.	Deutsch-Amerikanische Petroleum-Gesellsch., Hamburg.
4	Cargo vessel.	2	800	Gebr. Sulzer, Winterthur.	Howaldtswerke, Kiel.	Ham.-Südamerikanisch. Dampfschiffahrts-Gesellschaft, Hamburg.
5	do.	2	800	Prof. Junkers, Aachen.	Aktien-Gesellsch. "Weser," Brem.	Hamb'g-Amerika Linie, Hamburg.
6	Petroleum tank vessel.	2	1,150	Fried. Krupp Germaniawerft, Kiel.	Fr'd. Krupp, A. G. Germaniawerft, Kiel.	Deutsch-Amerikanische Petroleum-Gesellsch., Hamburg.
7	do.	2	1,150	do.	do.	do.
	Total,	13				

A NEW SINGLE-PHASE MOTOR.

By Lieutenant S. M. Robinson, U. S. N., Member.

This motor is a very recent development; in fact, it is still the subject of experiment in the larger sizes. The machines of this type that have been tested up to the present time show a slightly higher power factor with a slightly lower efficiency than the best forms of induction motors.

The motor consists of a stationary armature and commutator forming the stator of the machine, and a drum with short-circuited coil on it forming the rotor. The commutator and armature bear the same relation to each other that they do in the ordinary type of motor, but since they do not revolve they may be separated any desired distance and the commutator can be very readily replaced or repaired. Rotation of the motor is accomplished by revolving the brushes, which are supplied with single-phase alternating current. The rotor follows the brushes around, but is always a certain angle behind them.

The brushes on the commutator may be revolved either by hand or by a small auxiliary motor. When an intermittent motion, lasting only a short time, is desired the first method would be employed, but when the motion is to last for a longer period the small motor would be used. The method of connecting the brushes to the current supply is shown diagrammatically in Fig. 1. The current is led to two slip rings, which are revolved by the small variable-speed motor. Each slip ring is connected to one brush on the commutator and insulated from the other. The speed of the motor will be the same as that of the brushes, the coil taking up a definite position behind the brushes and staying there.

Fig. 2 shows a diagrammatic sketch of the motor. Its

action is a combination of transformer and motor principles. The alternating current supplied to the armature sets up a pulsating flux through the short-circuited coil when the latter is out of the plane of the brushes. This flux induces an E.M.F. in the coil and causes a current to flow in it. This current acts both to lower the reactance of the primary, thus causing a load current to flow in it, and to set up a second pulsating flux throughout the magnetic circuit. At a given instant the polarity of the rotor and stator will be as shown in the figure, two N-poles in this case, so that as the brushes are rotated in a clockwise direction the N-pole of the coil will be pushed along ahead of it by the N-pole of the brushes. As soon as the rotor commences to turn another effect is produced; the flux due to the coil cuts the conductors of the armature and sets up an electromotive force corresponding to the counter E.M.F. of any ordinary direct-current motor.

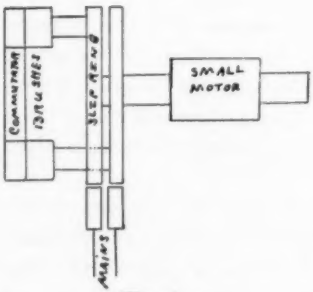


Fig. 1.

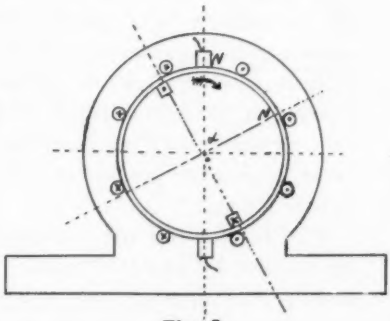


Fig. 2.

It can at once be seen why the power factor of this motor is so much higher than that of the single-phase series motor; the self-inductance of the field coils is entirely eliminated and that of the armature lowered very much by the transformer action of the motor.

The sparking troubles, however, persist, as is always the case with a commutator taking alternating current. Sparking is controlled by the same means as in the single-phase series motor, that is, by inserting resistance in the leads from

the commutator to the armature. However, there is a great difference between the two motors as regards the effects of sparking. Since the armature and commutator of this motor are separate the resistances can be inserted outside of the armature and thus avoid any increase in complication. It also becomes a simple matter to replace or repair these resistances and the commutator. These resistances, of course, lower the efficiency slightly and partly account for the difference in efficiency between this motor and the induction motor.

The high-power factor characteristic is most important, since it decreases very greatly the weight of the motor. The weight of the present alternating-current series motor is about twice that of a direct-current motor of the same power and speed.

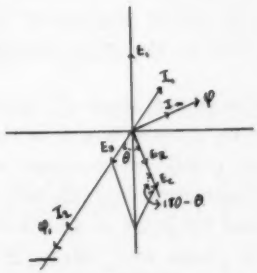


Fig. 3.

To analyze the action of the motor more in detail, refer to Figs. 2 and 3. In the vector diagram in Fig. 3 we have the following quantities:

Let E_1 = the primary supplied E.M.F.

E_c = the primary induced E.M.F., which will be equal and opposite to E_1 when the motor is stopped, but which combines with E_3 to balance E_1 when the motor is running.

E_3 = the generated or counter E.M.F. of the primary.

E_2 = the secondary E.M.F.

I_m = the magnetizing current of the primary, which sets up the flux φ and is 90 degrees in phase ahead of E_c, which is induced by φ.

I_1 = the primary load current, opposite in phase to I_2.
I_2 = the secondary load current, which produces the flux φ_1.
ω = the frequency of the supplied current $\times 2\pi$.
Z = the number of conductors on the armature.
N = the number of turns in the primary $= \frac{Z}{2}$.

In this case there is only one turn in the secondary.
n = the speed of the rotor in revolutions per second.
α = the angle between the brushes and the poles of the secondary (short-circuited coil).
L = the inductance of the secondary.
R = the resistance of the secondary.
T = the torque developed by the motor.
θ = the angle of lag of secondary current behind its E.M.F., that is, the angle between E_2 and I_2.

E_2 and E_c will be in phase, since E_c is induced by the flux φ, and E_2 is induced by $\varphi \cos \alpha$, which is the component passing through the coil; φ will be in phase with its current I_m, which is 90 degrees ahead of E_c. E_3 will be in phase with I_2, since it is generated by $\varphi_1 \sin \alpha$, which is in phase with I_2. I_1 will be opposite in phase to I_2, since it only flows to neutralize the flux φ_1. The resultant of E_3 and E_c must always be equal and opposite to E_1, the supplied voltage, otherwise the system would be unbalanced.

The flux φ_1, which is produced by I_2, can be resolved into $\varphi_1 \cos \alpha$, in line with the brushes, and $\varphi_1 \sin \alpha$, at right angles to the brushes; the first component causes the current I_1 in the primary; I_1 will always be just large enough to produce a flux which will neutralize this component of φ_1; the second component of φ_1 produces no effect on the primary by its pulsations, since it is at right angles to it; however, it will affect the secondary, but only that part of it which is at right angles to the coil, or $\varphi_1 \sin^2 \alpha$, will have any effect; so that if the reactance of the secondary alone is ωL, then in the motor it will be $\omega L \sin^2 \alpha$, since the reactance depends directly on

the flux of the circuit. This component, $\varphi_1 \sin a$, will also have an effect on the primary when there is any rotation of the secondary coil; due to the flux cutting the armature conductors a counter E.M.F. (marked E_3 in the diagram) will be set up in the primary, and it will be in phase with the secondary current I_2 since the latter produces the flux.

Since the armature and coil form the primary and secondary of a transformer the equations of the transformer may be made use of to get the relation between the different quantities.

From the transformer we have:

$$\frac{E_2}{E_c \cos a} = \frac{1}{N}, \text{ or, } E_2 = \frac{E_c \cos a}{N}, \text{ and}$$

$$\frac{I_1}{I_2 \cos a} = \frac{1}{N}, \text{ or, } I_1 = \frac{I_2 \cos a}{N}.$$

The impedance of the secondary being $\sqrt{R^2 + \omega^2 L^2 \sin^4 a}$, we have:

$$I_2 = \frac{E_2}{\sqrt{R^2 + \omega^2 L^2 \sin^4 a}} = \frac{E_c \cos a}{N\sqrt{R^2 + \omega^2 L^2 \sin^4 a}},$$

$$I_1 = \frac{E_c \cos^2 a}{N^2 \sqrt{R^2 + \omega^2 L^2 \sin^4 a}}.$$

The magnetic circuits of the primary and secondary are the same; therefore, their reactances will be proportional to the square of the number of turns in each; therefore, the reactance of the primary will be $\omega L N^2$, and we have:

$$I_m = \frac{E_c}{\omega L N^2}.$$

The flluxes φ and φ_1 will be proportional to the ampère-turns producing them, since they have the same magnetic circuit; so we have:

$$\frac{\varphi_1}{\varphi} = \frac{I_2}{N I_m} = \frac{E_c \cos a}{N\sqrt{R^2 + \omega^2 L^2 \sin^4 a}} \times \frac{\omega L N^2}{N E_c} = \frac{\omega L \cos a}{\sqrt{R^2 + \omega^2 L^2 \sin^4 a}}.$$

Again, from the transformer we have:

$$\varphi = \frac{E_c}{\omega N};$$

therefore,

$$\varphi_1 = \frac{E_c}{\omega N} \times \frac{\omega L \cos a}{\sqrt{R^2 + \omega^2 L^2 \sin^4 a}} = \frac{L E_c \cos a}{N \sqrt{R^2 + \omega^2 L^2 \sin^4 a}},$$

and $\varphi_1 \sin a$ (the generating component) $= \dfrac{L E_c \sin a \cos a}{N \sqrt{R^2 + \omega^2 L^2 \sin^4 a}}$.

The counter E.M.F., E_3,

$$= \frac{\text{flux} \times \text{number of conductors} \times \text{speed} \times \text{number of poles}}{\text{number of paths in parallel}}$$

$$= \frac{\varphi_1 \sin a \times 2N \times n \times 2}{2} = 2\varphi_1 \sin a \, Nn = \frac{2 L E_c \sin a \cos a \, n}{\sqrt{R^2 + \omega^2 L^2 \sin^4 a}}.$$

In any motor we have

$$2\pi n T = EI.$$

In this case $E = E_3$ (counter E.M.F.), and $I = I_1 + I_m \sin \theta$, or that part of the primary current which is opposite in phase to E_3.

Since θ is the lag of secondary current behind its E.M.F., we have

$$\sin \theta = \frac{\omega L \sin^2 a}{\sqrt{R^2 + \omega^2 L^2 \sin^4 a}}.$$

Then,

$$I_1 + I_m \sin \theta = \frac{E_c \cos^2 a}{N^2 \sqrt{R^2 + \omega^2 L^2 \sin^4 a}} + \frac{E_c}{\omega L N^2} \times \frac{\omega L \sin^2 a}{\sqrt{R^2 + \omega^2 L^2 \sin^4 a}}$$

$$= \frac{E_c \cos^2 a}{N^2 \sqrt{R^2 + \omega^2 L^2 \sin^4 a}} + \frac{E_c \sin^2 a}{N^2 \sqrt{R^2 + \omega^2 L^2 \sin^4 a}}$$

$$= \frac{E_c}{N^2 \sqrt{R^2 + \omega^2 L^2 \sin^4 a}}.$$

Therefore, $2\pi n T = \dfrac{2 L E_c \sin a \cos a \, n}{\sqrt{R^2 + \omega^2 L^2 \sin^4 a}} \times \dfrac{E_c}{N^2 \sqrt{R^2 + \omega^2 L^2 \sin^4 a}}$,

or, $$T = \frac{LE_c^2}{\pi N^2} \times \frac{\sin a \cos a}{R^2 + \omega^2 L^2 \sin^4 a}.$$

From the triangle of E.M.F.'s we have

$$E_3^2 + E_c^2 + 2E_3 E_c \cos\theta = E_1^2,$$

or, $$\frac{4L^2E_c^2 \sin^2 a \cos^2 a\, n^2}{R^2 + \omega^2 L^2 \sin^4 a} + E_c^2 + \frac{4E_c^2 RL \sin a \cos a\, n}{R^2 + \omega^2 L^2 \sin^4 a} = E_1^2,$$

or,

$$E_c^2[(2L \sin a \cos a\, n + R)^2 + \omega^2 L^2 \sin^4 a] = E_1^2(R^2 + \omega^2 L^2 \sin^4 a),$$

and $$E_c^2 = \frac{E_1^2(R^2 + \omega^2 L^2 \sin^4 a)}{(2L \sin a \cos a\, n + R)^2 + \omega^2 L^2 \sin^4 a}.$$

Substituting this value of E_c in the equation for the torque we have

$$T = \frac{LE_1^2}{\pi N^2} \times \frac{\sin a \cos a}{(2L \sin a \cos a\, n + R)^2 + \omega^2 L^2 \sin^4 a}. \qquad (1)$$

To find what value of a will make T a maximum, differentiate with regard to T and a and place $\frac{dT}{da} = 0$, and we have

$$\frac{dT}{da} = 0 = \frac{\cos^2 a}{(2L \sin a \cos a\, n + R)^2 + \omega^2 L^2 \sin^4 a} -$$

$$\frac{\sin^2 a}{(2L \sin a \cos a\, n + R)^2 + \omega^2 L^2 \sin^4 a} -$$

$$\frac{\sin a \cos a[2(2L \sin a \cos a n + R)(2Ln)(1 - 2\sin^2 a) + 4\omega^2 L^2 \sin^3 a \cos a]}{[(2L \sin a \cos a\, n + R)^2 + \omega^2 L^2 \sin^4 a]^2},$$

or, $$(1 - 2\sin^2 a)[(2L \sin a \cos a\, n + R)^2 + \omega^2 L^2 \sin^4 a] -$$

$$\sin a \cos a[4Ln(1 - 2\sin^2 a)(2L \sin a \cos a n + R) + 4\omega^2 L^2 \sin^3 a \cos a] = 0.$$

Reducing, we have

$$R^2 - 2\sin^2 a(2L^2 n^2 + R^2) + L^2 \sin^4 a(3 - 2\sin^2 a)(4n^2 - \omega^2) = 0. \qquad (2)$$

This equation, which gives the value of a for maximum torque, is best represented by curves. By giving different values to n, such as 2ω, ω, etc., a series of curves can be

plotted for various values of the reactance ωL in terms of R. These curves are shown in Fig. 4. Here it is seen that when $n = 2\omega$ (or larger values), there are two parts to the curve, that is, there are two values of a which will make T a maximum; these two maxima are not of the same value, however, as is seen in the next set of curves, which are shown in Fig. 5. Here the values of T, corresponding to the values of a which make it a maximum, are plotted for various speeds.

Figs. 6, 7, 8 and 9 represent (1), the general equation for the torque; its values, corresponding to all values of a from

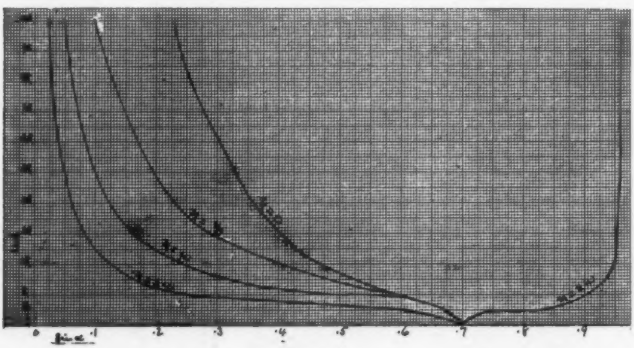


Fig. 4.

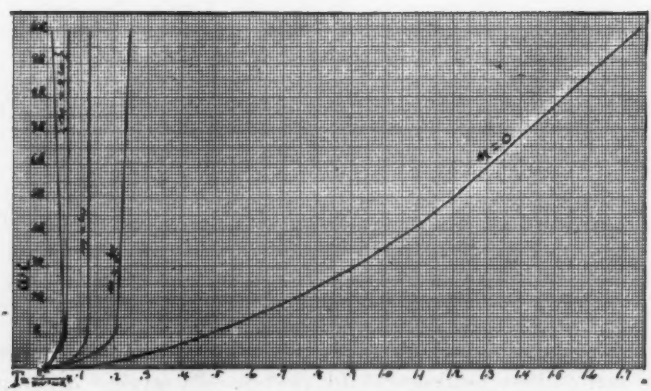


Fig. 5.

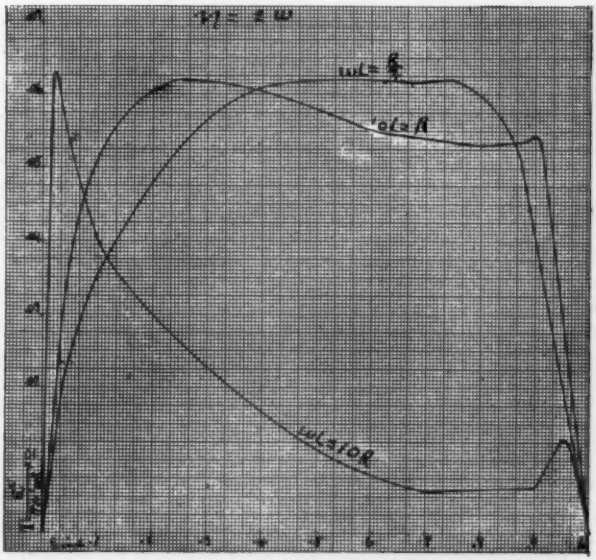


Fig. 6.

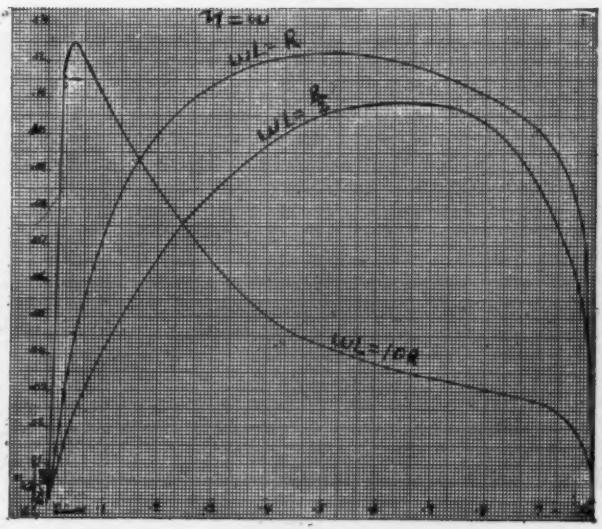


Fig. 7.

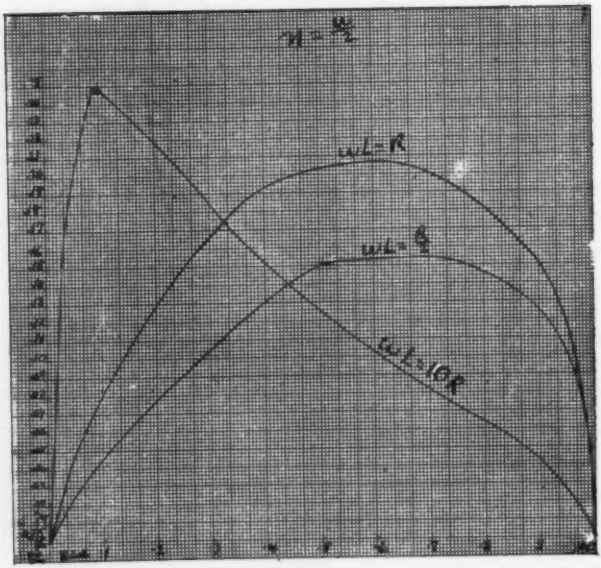


Fig. 8.

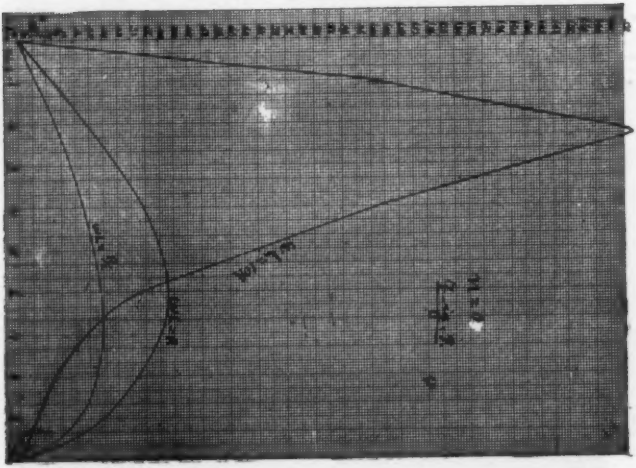


Fig. 9.

0 degrees to 90 degrees, are given. Here the maximum points are shown very clearly, and the two maxima on the high speed ($n = 2\omega$) are also shown; it is seen that for very large values of the reactance the second maximum is very small, and as the reactance decreases the two points tend to become one.

In all the figures mentioned the curve for $n = 0$ represents conditions at standstill or starting; it will be noticed that the value of the maximum torque in this case is much larger than the corresponding running torque. It is also seen that for any given set of conditions the maximum torque that the motor can develop is increased very greatly as the speed is decreased, also as the rotor resistance is decreased.

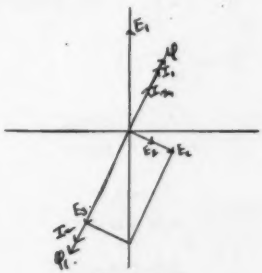


Fig. 10.

If the rotor resistance were so small that, compared with the reactance, it could be considered negligible or zero, we should have a different set of conditions, which would be as shown in Figure 10. This is the same as Figure 5, except that the angle θ has now become 90 degrees, and consequently the diagram is much simpler. Since only the reactance now operates to determine the secondary current the angle of lag will be 90 degrees, as has been stated. This brings I_m into phase with I_1, and the triangle of E.M.F.'s becomes a right triangle. By using the same formulae as in the first case, where R was not negligible, and taking account of the simpler relations, we have

$$E_2 = \frac{E_c \cos a}{N};$$

$$I_2 = \frac{E_2}{\omega L \sin^2 a} = \frac{E_c \cos a}{\omega L N \sin^2 a};$$

$$I_1 = \frac{I_2 \cos a}{N} = \frac{E_c \cos^2 a}{\omega L N^2 \sin^2 a};$$

$$I_m = \frac{E_c}{\omega L N^2};$$

$$I_1 + \mathrm{I}_m = \frac{E_c \cos^2 a}{\omega L N^2 \sin^2 a} + \frac{E_c}{\omega L N^2} = \frac{E_c}{\omega L N^2 \sin^2 a};$$

$$\frac{\varphi_1}{\varphi} = \frac{I_2}{N I_m} = \frac{E_c \cos a}{\omega L N \sin^2 a} \times \frac{\omega L N^2}{N E_c} = \frac{\cos a}{\sin^2 a};$$

$$\varphi = \frac{E_c}{\omega N};$$

$$\varphi_1 = \frac{E_c}{\omega N} \times \frac{\cos a}{\sin^2 a};$$

$$\varphi_1 \sin a = \frac{E_c \cos a}{\omega N \sin a};$$

$$E_3 = \frac{2 E_c \cos a \, n}{\omega \sin a};$$

$$T = \frac{E_c^2 \cos a}{\pi \omega^2 N^2 L \sin^3 a};$$

$$E_3^2 + E_c^2 = E_1^2;$$

$$\frac{4 E_c^2 \cos^2 a \, n^2}{\omega^2 \sin^2 a} + E_c^2 = E_1^2;$$

$$E_c^2 = \frac{E_1^2 \omega^2 \sin^2 a}{4 n^2 \cos^2 a + \omega^2 \sin^2 a}.$$

Substituting in the equation for T we have

$$T = \frac{E_1^2}{\pi N^2 L} \times \frac{\cos a}{\sin a (4 n^2 \cos^2 a + \omega^2 \sin^2 a)} \qquad (3)$$

To find the value of a which will make T a maximum, we differentiate as before, and we have

$$\frac{dT}{da} = 0 = \frac{-\sin a}{\sin a(4n^2\cos^2 a + \omega^2 \sin^2 a)} - \frac{\cos^2 a}{\sin^2 a\,(4n^2\cos^2 a + \omega^2 \sin^2 a)}$$
$$- \frac{\cos a\,(-8n^2 \sin a \cos a + 2\omega^2 \sin a \cos a)}{\sin a\,(4n^2\cos^2 a + \omega^2 \sin^2 a)^2}.$$

Reducing this equation, we have

$$2\sin^4 a\,(4n^2 - \omega^2) - 3\sin^2 a\,(4n^2 - \omega^2) = -4n^2,$$

or,
$$\sin^4 a - \tfrac{3}{2}\sin^2 a = -\frac{2n^2}{4n^2 - \omega^2}$$

or,
$$(\sin^2 a - \tfrac{3}{4})^2 = \tfrac{9}{16} - \frac{2n^2}{4n^2 - \omega^2} = \frac{4n^2 - 9\omega^2}{16(4n^2 - \omega^2)}.$$

$$\sin^2 a - \tfrac{3}{4} = \tfrac{1}{4}\sqrt{\frac{4n^2 - 9\omega^2}{4n^2 - \omega^2}};$$

$$\sin a = \sqrt{\frac{3 + \sqrt{\dfrac{4n^2 - 9\omega^2}{4n^2 - \omega^2}}}{2}}. \qquad (4)$$

It is seen that for values of n less than $\frac{3}{2}\omega$ this expression gives an imaginary value for a. By plotting a set of curves corresponding to equation (3), giving the values of T for all values of a, the expression for the maximum torque becomes more clear. These curves are shown in Fig. 11. The maximum torque obtainable is infinite and occurs when $a = 0$, or, in other words, when the coil is at right angles to the brushes. But for values of n greater than $\frac{3}{2}\omega$ there is a second maximum point, as is shown in the curve where $n = 2\omega$. This second maximum is the one given by equation (4).

The same expression for the torque in this special case could have been obtained by substituting $R = 0$ directly into the general expression derived at first.

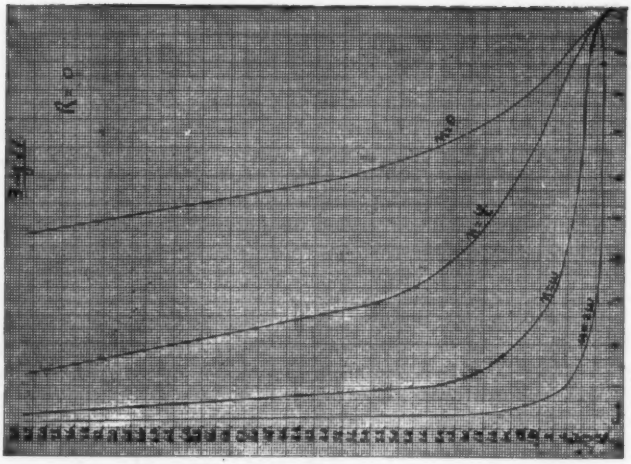


Fig. 11.

From the expression for the torque it is very simple to get an expression for the power factor. In Figure 12 the two components of the primary current, I_1 and I_m, have been

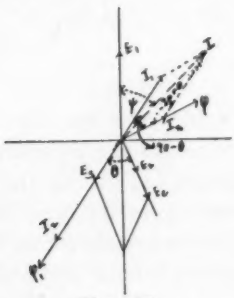


Fig. 12.

combined to give the resultant primary current I. The angle ψ is the lag of this current behind the primary E.M.F., E_1, so that $\cos\psi$ will be the power factor, and $E_1 I \cos\psi$ will represent the power supplied to the motor. The loss of power will be $R I_2^2$, and the work done will be $2\pi n T$.

Therefore, $E_1 I \cos\psi = 2\pi n T + R I_2^2$.

From the triangle of currents we have

$$I^2 = I_1^2 + I_m^2 - 2 I_1 I_m \cos(90 + \theta) = I_1^2 + I_m^2 + 2 I_1 I_m \sin\theta.$$

Substituting for these quantities the values already derived, we have

$$\begin{aligned} I^2 &= \frac{E_c^2 \cos^4\alpha}{N^4 (R^2 + \omega^2 L^2 \sin^4\alpha)} + \frac{E_c^2}{\omega^2 L^2 N^4} \\ &\quad + \frac{2 E_c^2 \cos^2\alpha}{\omega L N^4 \sqrt{R^2 + \omega^2 L^2 \sin^4\alpha}} \times \frac{\omega L \sin^2\alpha}{\sqrt{R^2 + \omega^2 L^2 \sin^4\alpha}} \\ &= \frac{E_1^2 \cos^4\alpha}{N^4 [(2Ln \sin\alpha \cos\alpha + R)^2 + \omega^2 L^2 \sin^4\alpha]} \\ &\quad + \frac{E_1^2 (R^2 + \omega^2 L^2 \sin^4\alpha)}{\omega^2 L^2 N^4 [(2Ln \sin\alpha \cos\alpha + R)^2 + \omega^2 L^2 \sin^4\alpha]} \\ &\quad + \frac{2 E_1^2 \sin^2\alpha \cos^2\alpha}{N^4 [(2Ln \sin\alpha \cos\alpha + R)^2 + \omega^2 L^2 \sin^4\alpha]}. \end{aligned}$$

Reducing, we have

$$\begin{aligned} I^2 &= \frac{E_1^2 [\omega^2 L^2 (\cos^2\alpha + \sin^2\alpha)^2 + R^2]}{\omega^2 L^2 N^4 [(2Ln \sin\alpha \cos\alpha + R)^2 + \omega^2 L^2 \sin^4\alpha]} \\ &= \frac{E_1^2 (R^2 + \omega^2 L^2)}{\omega^2 L^2 N^4 [(2Ln \sin\alpha \cos\alpha + R)^2 + \omega^2 L^2 \sin^4\alpha]}. \end{aligned}$$

Therefore, $$I = \frac{E_1 \sqrt{R^2 + \omega^2 L^2}}{\omega L N^2 \sqrt{(2Ln \sin\alpha \cos\alpha + R)^2 + \omega^2 L^2 \sin^4\alpha}},$$

and $$E_1 I \cos\psi = \frac{E_1^2 \sqrt{R^2 + \omega^2 L^2} \cos\psi}{\omega L N^2 \sqrt{(2Ln \sin\alpha \cos\alpha + R)^2 + \omega^2 L^2 \sin^4\alpha}},$$

$$2\pi n T = \frac{2Ln \sin\alpha \cos\alpha \, E_1^2}{N^2 [(2Ln \sin\alpha \cos\alpha + R)^2 + \omega^2 L^2 \sin^4\alpha]};$$

$$R I_2^2 = \frac{R E_e^2 \cos^2 a}{N^2 (R^2 + \omega^2 L^2 \sin^4 a)}$$

$$= \frac{R E_1^2 \cos^2 a}{N^2 [(2Ln \sin a \cos a + R)^2 + \omega^2 L^2 \sin^4 a]};$$

therefore,

$$\frac{E_1^2 \sqrt{R^2 + \omega^2 L^2} \cos \psi}{\omega L N^2 \sqrt{(2Ln \sin a \cos a + R)^2 + \omega^2 L^2 \sin^4 a}} =$$

$$\frac{2Ln \sin a \cos a \, E_1^2}{N^2 [(2Ln \sin a \cos a + R)^2 + \omega^2 L^2 \sin^4 a]} +$$

$$\frac{R E_1^2 \cos^2 a}{N^2 [(2Ln \sin a \cos a + R)^2 + \omega^2 L^2 \sin^4 a]};$$

or,

$$\cos \psi = \frac{\omega L (R \cos^2 a + 2Ln \sin a \cos a)}{\sqrt{R^2 + \omega^2 L^2} \sqrt{(2Ln \sin a \cos a + R)^2 + \omega^2 L^2 \sin^4 a}}. \quad (5)$$

In Figure 13 the values of ψ corresponding to various values of a are plotted. In each case the maximum value occurs when $a = 0$, and is the same for all speeds for a given value of the reactance ωL. When $a = 0$, however, the torque is also zero, and therefore the action is wholly that of a transformer, except in the special case where $R = 0$.

In this latter case an expression for $\cos \psi$ could be derived in the same way as for the preceding general case, but it is

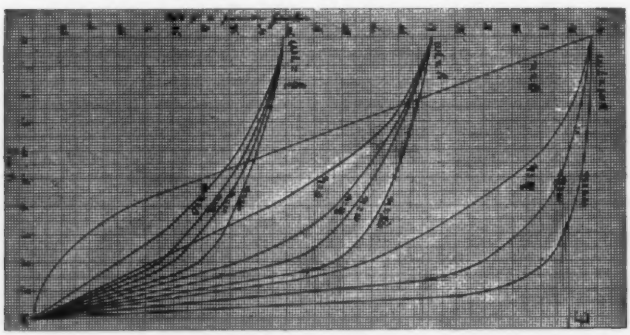


Fig. 13.

simpler to arrive at it by substituting $R = 0$ directly into the general expression. We have then

$$\cos\psi = \frac{\omega L(2Ln\sin\alpha\cos\alpha)}{\omega L\sqrt{4L^2n^2\sin^2\alpha\cos^2\alpha + \omega^2L^2\sin^4\alpha}}$$

$$= \frac{2n\cos\alpha}{\sqrt{4n^2\cos^2\alpha + \omega^2\sin^2\alpha}}. \qquad (6)$$

This equation is plotted as a set of curves in Figure 14. The maximum value occurs, as before, when $\alpha = 0$, and, in this case, is unity.

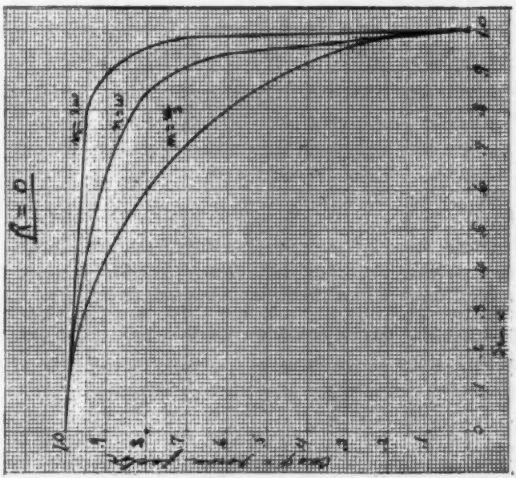


Fig. 14.

In all the previous discussion the resistance of the armature has been neglected, as have also the effects of magnetic leakage, hysteresis and eddy currents; but none of these in any way affect the theory of the motor, they only alter slightly the numerical values and make the results very much more complicated.

Having developed the theory of the motor, it now becomes simpler to follow its action. As has already been stated the

speed of the rotor is the same as that of the brushes, the angle of lag changing to accommodate a change of load or speed, following the curves already shown. When the brushes stop, the coil will also stop and always rest in the plane of the brushes; for, suppose there were a large centrifugal force being exerted which would tend to carry the coil past the brushes, as soon as the coil passed the brushes the same conditions would exist as those shown in Figure 2 if the direction of rotation were reversed; it is evident that the rotor would be trying to pull the two N-poles together, and unless the centrifugal force is greater than the maximum possible torque of the motor it would be impossible to accomplish this; on the other hand, they would be forced apart till the coil came back into the plane of the brushes, when the motor would cease to exert torque. In other words, the coil is held rigidly in the plane of the brushes at standstill, and rotation is due to a constant effort on the part of the coil to get back into the plane of the brushes. When the motor is stopped it becomes a simple transformer with its secondary circuit open or without any secondary, so that the full reactance of the primary comes into effect, and the only current that will flow will be I_m, the magnetizing current, and this will be practically 90 degrees in phase behind E_1, so that it will represent very little loss of power. Consequently, it is not necessary to open the main circuit when stopping unless the stop is for a long time.

The speed of the motor is independent of fluctuations of the generator or of line voltage. The variations of the generator would alter both ω and E_1, but this would simply cause the value of α to change to meet the new conditions.

The same is true of variations of the load on the motor; so long as the maximum torque corresponding to any given set of conditions is not exceeded the angle α will shift enough to meet any change of load.

If this motor proves successful in the large sizes it will probably find its greatest fields of usefulness in railway work, and as the motive power on board ship if the electric drive

should be adopted. For the latter purpose it would have several advantages over any other form of motor that would be used for this purpose, as, for example, the induction motor. First, the speed of the turbine-driven generator would not have to be changed at all; this would probably be its greatest advantage, as it would give a very efficient turbine; second, the regulation of the speed of the turbine would not have to be close, as the fluctuations would not affect the speed of the motor at all; third, backing would be a simpler operation, as it would be only necessary to reverse the direction of rotation of the small motor driving the brushes; fourth, it would be simpler to regulate the speed of the ship, as this would also be done by varying the speed of the small motor; fifth, it would not be necessary to break the main circuit, either for backing or for short stops; sixth, the starting torque is very high.

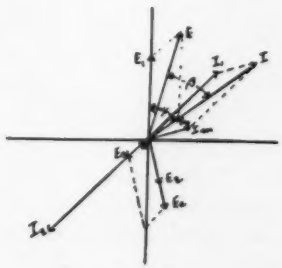


Fig. 15.

Before concluding, it might be well to consider the effect of resistance in two special cases. It has already been stated that this does not change the theory any, but makes a general equation very complicated. This is not true of any particular case, however, where all the conditions are given; the expression becomes very simple indeed in that case.

In the first case very high resistances are assumed in the primary and secondary. The conditions chosen are:

$$n = \frac{\omega}{2};$$

$$R = \omega L \text{ (resistance = reactance)};$$

r (primary resistance) = primary reactance = $\omega L N^2$.

Then, $$R = rN^2.$$

The new set of conditions is shown in Figure 15. Here we have a new E.M.F., E_4, which is the rI drop in the primary, and consequently in phase with I. This E.M.F., combined with E_1, will give the supplied E.M.F., marked E in the figure.

From formulae already deduced we have

$$I = \frac{E_1 \sqrt{R^2 + \omega^2 L^2}}{\omega L N^2 \sqrt{(2Ln \sin\alpha \cos\alpha + R)^2 + \omega^2 L^2 \sin^4\alpha}}$$

$$= \frac{\sqrt{2}\, E_1}{RN^2 \sqrt{(\sin\alpha \cos\alpha + 1)^2 + \sin^4\alpha}};$$

$$\cos\phi = \frac{\omega L (R\cos^2\alpha + 2Ln \sin\alpha \cos\alpha)}{\sqrt{R^2 + \omega^2 L^2}\sqrt{(2Ln \sin\alpha \cos\alpha + R)^2 + \omega^2 L^2 \sin^4\alpha}}$$

$$= \frac{\cos^2\alpha + \sin\alpha \cos\alpha}{\sqrt{2}\sqrt{(\sin\alpha \cos\alpha + 1)^2 + \sin^4\alpha}};$$

$$E_4 = rI = \frac{r\sqrt{2}\, E_1}{RN^2 \sqrt{(\sin\alpha \cos\alpha + 1)^2 + \sin^4\alpha}}$$

$$= \frac{\sqrt{2}\, E_1}{\sqrt{(\sin\alpha \cos\alpha + 1)^2 + \sin^4\alpha}}.$$

From the triangle of E.M.F.'s we have

$$E^2 = E_1^2 + E_4^2 + 2E_1 E_4 \cos\phi = E_1^2 + \frac{2E_1^2}{(\sin\alpha \cos\alpha + 1)^2 + \sin^4\alpha}$$

$$+ \frac{2\sqrt{2}\, E_1^2}{\sqrt{(\sin\alpha \cos\alpha + 1)^2 + \sin^4\alpha}} \times \frac{\cos^2\alpha + \sin\alpha \cos\alpha}{\sqrt{2}\sqrt{(\sin\alpha \cos\alpha + 1)^2 + \sin^4\alpha}}$$

$$= E_1^2\left[1 + \frac{2}{(\sin\alpha\cos\alpha + 1)^2 + \sin^4\alpha} + \frac{2(\cos^2\alpha + \sin\alpha\cos\alpha}{(\sin\alpha\cos\alpha + 1)^2 + \sin^4\alpha}\right]$$

$$= \frac{E_1^2(\cos^2\alpha + 4\sin\alpha\cos\alpha + 4)}{(\sin\alpha\cos\alpha + 1)^2 + \sin^4\alpha};$$

or,
$$E_1^2 = \frac{E^2[(\sin\alpha\cos\alpha + 1)^2 + \sin^4\alpha]}{\cos^2\alpha + 4\sin\alpha\cos\alpha + 4},$$

and
$$E_1 = \frac{E\sqrt{(\sin\alpha\cos\alpha + 1)^2 + \sin^4\alpha}}{\sqrt{\cos^2\alpha + 4\sin\alpha\cos\alpha + 4}}. \qquad (7)$$

Let β equal the angle of lag of I behind E.

Then, $\cos\beta =$ the power factor,

and $EI\cos\beta =$ the power supplied to the circuit;

also, $2\pi nT + RI_2^2 + rI^2 =$ work performed.

Therefore, $EI\cos\beta = 2\pi nT + RI_2^2 + rI^2;$

$$EI\cos\beta = \frac{E^2\sqrt{2}\cos\beta}{RN^2\sqrt{(\sin\alpha\cos\alpha + 1)^2 + \sin^4\alpha}} \times \frac{\sqrt{(\sin\alpha\cos\alpha + 1)^2 + \sin^4\alpha}}{\sqrt{\cos^2\alpha + 4\sin\alpha\cos\alpha + 4}}$$

$$= \frac{\sqrt{2}\,E^2\cos\beta}{RN^2\sqrt{\cos^2\alpha + 4\sin\alpha\cos\alpha + 4}};$$

$$2\pi nT = \frac{2\pi nLE_1^2}{\pi N^2} \times \frac{\sin\alpha\cos\alpha}{(2Ln\sin\alpha\cos\alpha + R)^2 + \omega^2L^2\sin^4\alpha}$$

$$= \frac{E_1^2\sin\alpha\cos\alpha}{RN^2[(\sin\alpha\cos\alpha + 1)^2 + \sin^4\alpha]}$$

$$= \frac{E^2\sin\alpha\cos\alpha}{RN^2(\cos^2\alpha + 4\sin\alpha\cos\alpha + 4)};$$

$$RI_2^2 = \frac{RE_c^2 \cos^2\alpha}{N^2(R^2 + \omega^2 L^2 \sin^4\alpha)}$$

$$= \frac{RE_1^2 \cos^2\alpha}{N^2\left[(2Ln \sin\alpha\cos\alpha + R)^2 + \omega^2 L^2 \sin^4\alpha\right]}$$

$$= \frac{E_1^2 \cos^2\alpha}{RN^2\left[(\sin\alpha\cos\alpha + 1)^2 + \sin^4\alpha\right]}$$

$$= \frac{E^2 \cos^2\alpha}{RN^2(\cos^2\alpha + 4\sin\alpha\cos\alpha + 4)};$$

$$rI^2 = \frac{2E_1^2 r}{R^2N^4\left[(\sin\alpha\cos\alpha + 1)^2 + \sin^4\alpha\right]}$$

$$= \frac{2E^2}{RN^2(\cos^2\alpha + 4\sin\alpha\cos\alpha + 4)}.$$

Therefore, $\dfrac{\sqrt{2}\,E^2\cos\beta}{RN^2\sqrt{\cos^2\alpha + 4\sin\alpha\cos\alpha + 4}}$

$$= \frac{E^2 \sin\alpha\cos\alpha}{RN^2(\cos^2\alpha + 4\sin\alpha\cos\alpha + 4)} + \frac{E^2\cos^2\alpha}{RN^2(\cos^2\alpha + 4\sin\alpha\cos\alpha + 4)} + \frac{2E^2}{RN^2(\cos^2\alpha + 4\sin\alpha\cos\alpha + 4)};$$

or,
$$\cos\beta = \frac{\cos^2\alpha + \sin\alpha\cos\alpha + 2}{\sqrt{2}\sqrt{\cos^2\alpha + 4\sin\alpha\cos\alpha + 4}}. \qquad (8)$$

Since efficiency $= \dfrac{\text{useful work}}{\text{energy supplied}}$, we have

$$\eta \text{ (efficiency)} = \frac{E^2 \sin\alpha\cos\alpha}{RN^2(\cos^2\alpha + 4\sin\alpha\cos\alpha + 4)} \Big/ \frac{E^2(\cos^2\alpha + \sin\alpha\cos\alpha + 2)}{RN^2(\cos^2\alpha + 4\sin\alpha\cos\alpha + 4)}$$

$$= \frac{\sin\alpha\cos\alpha}{\cos^2\alpha + \sin\alpha\cos\alpha + 2}. \qquad (9)$$

To find the value of a to make η a maximum, put $\frac{d\eta}{da} = 0$, and we have

$$0 = \frac{\cos^2 a}{\cos^2 a + \sin a \cos a + 2} - \frac{\sin^2 a}{\cos^2 a + \sin a \cos a + 2} - \frac{\sin a \cos a (-2 \sin a \cos a + \cos^2 a - \sin^2 a)}{(\cos^2 a + \sin a \cos a + 2)^2};$$

or,
$$3 - 5 \sin^2 a = 0,$$
$$\sin a = \sqrt{\tfrac{3}{5}} = \sqrt{.6} \qquad (10)$$

Substituting (10) in (9), we have

$$\text{Max. } \eta = \frac{\sqrt{.6} \times \sqrt{.4}}{.4 + \sqrt{.6} \times .4 + 2} = 17 \text{ per cent.} \qquad (11)$$

This value is very low, as was to be expected, on account of the very high assumed values of the resistances r and R.

To find the equation for the torque, substitute in (1), and we have

$$T = \frac{LE_1^2}{\pi N^2} \times \frac{\sin a \cos a}{(2Ln \sin a \cos a + R)^2 + \omega^2 L^2 \sin^4 a}$$
$$= \frac{E^2 \sin a \cos a}{\omega \pi N^2 R (\cos^2 a + 4 \sin a \cos a + 4)}. \qquad (12)$$

To find the value of a to make this a maximum, put $\frac{dT}{da} = 0$, and we have

$$0 = \frac{\cos^2 a}{\cos^2 a + 4 \sin a \cos a + 4} - \frac{\sin^2 a}{\cos^2 a + 4 \sin a \cos a + 4} - \frac{\sin a \cos a (-2 \sin a \cos a + 4 \cos^2 a - 4 \sin^2 a)}{(\cos^2 a + 4 \sin a \cos a + 4)^2};$$

or,
$$5 - 9 \sin^2 a = 0,$$

and,
$$\sin a = \frac{\sqrt{5}}{3}. \qquad (13)$$

Substituting (13) in (12), we have

$$\text{Max. } T = \frac{E^2}{\omega\pi N^2 R} \times .077 \tag{14}$$

Substituting (10) in (12) we have

$$T \text{ for max. } \eta = \frac{E^2}{\omega\pi N^2 R} \times .077 \tag{15}$$

Maximum and most efficient torques are nearly the same in this case.

In the second case a more practical set of conditions is assumed. The conditions are:

$$n = \frac{\omega}{2};$$

$$R = 0;$$

$$r = \frac{1}{10}\omega L N^2.$$

This value of r is rather high even in this case. This case is shown in Figure 16, which is somewhat simpler than Figure 15, since $\theta = 90$ degrees when $R = 0$. From equations already deduced in this case we have

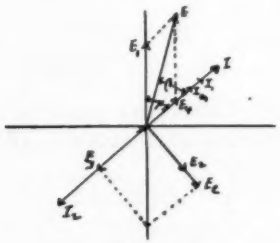


Fig. 16.

$$I = \frac{E_c}{\omega L N^2 \sin^2\alpha} = \frac{E_1 \omega \sin\alpha}{\omega L N^2 \sin^2\alpha \sqrt{4n^2\cos^2\alpha + \omega^2 \sin^2\alpha}}$$

$$= \frac{E_1}{\omega L N^2 \sin\alpha} = \frac{E_1}{10r \sin\alpha};$$

$$\cos\psi = \frac{2n\cos\alpha}{\sqrt{4n^2\cos^2\alpha + \omega^2\sin^2\alpha}} = \cos\alpha;$$

$$E_4 = rI = \frac{E_1}{10\sin\alpha}.$$

From the triangle of E.M.F.'s

$$E^2 = E_1^2 + E_4^2 + 2E_1E_4\cos\psi$$

$$= E_1^2 + \frac{E_1^2}{100\sin^2\alpha} + \frac{2E_1^2\cos\alpha}{10\sin\alpha}$$

$$= \frac{E_1^2(100\sin^2\alpha + 20\sin\alpha\cos\alpha + 1)}{100\sin^2\alpha};$$

$$E_1^2 = \frac{100\sin^2\alpha\, E^2}{100\sin^2\alpha + 20\sin\alpha\cos\alpha + 1};$$

$$E_1 = \frac{10\sin\alpha\, E}{\sqrt{100\sin^2\alpha + 20\sin\alpha\cos\alpha + 1}}. \qquad (16)$$

Letting β = angle of lag between E and I, as before, we have

$$EI\cos\beta = 2\pi nT + rI^2, \text{ since } RI_2^2 = 0.$$

$$EI\cos\beta = \frac{EE_1\cos\beta}{10r\sin\alpha} = \frac{E^2\cos\beta}{r\sqrt{100\sin^2\alpha + 20\sin\alpha\cos\alpha + 1)}};$$

$$2\pi nT = \frac{2\pi nE_1^2}{\pi N^2 L} \times \frac{\cos\alpha}{\sin\alpha(4n^2\cos^2\alpha + \omega^2\sin^2\alpha)}$$

$$= \frac{10E^2\sin\alpha\cos\alpha}{r(100\sin^2\alpha + 20\sin\alpha\cos\alpha + 1)};$$

$$rI^2 = \frac{rE_1^2}{100r^2\sin^2\alpha} = \frac{E^2}{r(100\sin^2\alpha + 20\sin\alpha\cos\alpha + 1)};$$

$$\therefore \frac{E^2 \cos\beta}{r\sqrt{100\sin^2\alpha + 20\sin\alpha\cos\alpha + 1}} = \frac{10E^2\sin\alpha\cos\alpha}{r(100\sin^2\alpha + 20\sin\alpha\cos\alpha + 1)} + \frac{E^2}{r(100\sin^2\alpha + 20\sin\alpha\cos\alpha + 1)};$$

$$\cos\beta = \frac{10\sin\alpha\cos\alpha + 1}{\sqrt{100\sin^2\alpha + 20\sin\alpha\cos\alpha + 1}}. \qquad (17)$$

As before, $\eta = \dfrac{\text{useful work}}{\text{energy supplied}}$,

or,

$$\eta = \frac{\dfrac{10E^2\sin\alpha\cos\alpha}{r(100\sin^2\alpha + 20\sin\alpha\cos\alpha + 1)}}{\dfrac{E^2(10\sin\alpha\cos\alpha + 1)}{r(100\sin^2\alpha + 20\sin\alpha\cos\alpha + 1)}} = \frac{10\sin\alpha\cos\alpha}{10\sin\alpha\cos\alpha + 1}. \qquad (18)$$

To find α for maximum η, put $\frac{d\eta}{d\alpha} = 0$, as before, and we have

$$0 = \frac{\cos^2\alpha}{10\sin\alpha\cos\alpha + 1} - \frac{\sin^2\alpha}{10\sin\alpha\cos\alpha + 1} - \frac{10\sin\alpha\cos\alpha(\cos^2\alpha - \sin^2\alpha)}{(10\sin\alpha\cos\alpha + 1)^2};$$

or,

$$1 - 2\sin^2\alpha = 0,$$

$$\sin\alpha = \frac{1}{\sqrt{2}}. \qquad (19)$$

Substituting (19) in (18), we have

$$\text{Max. } \eta = \tfrac{5}{6} = 83\tfrac{1}{3} \text{ per cent.} \qquad (20)$$

If r had been $\frac{1}{100}\omega LN^2$, the maximum efficiency would have been 98 per cent.; so the effect of high resistance is readily seen.

Torque is obtained by substituting in the general equation

$$T = \frac{E_1^2}{\pi N^2 L} \times \frac{\cos a}{\sin a\,(4r^2 \cos^2 a + \omega^2 \sin^2 a)}$$

$$= \frac{100\,E^2 \sin a \cos a}{\pi N^2 \omega^2 L\,(100 \sin^2 a + 20 \sin a \cos a + 1)}$$

$$= \frac{10\,E^2 \sin a \cos a}{\pi \omega r\,(100 \sin^2 a + 20 \sin a \cos a + 1)}. \qquad (21)$$

Putting $\frac{dT}{da} = 0$ to get the maximum, we have

$$0 = \frac{\cos^2 a}{100 \sin^2 a + 20 \sin a \cos a + 1} - \frac{\sin^2 a}{100 \sin^2 a + 20 \sin a \cos a + 1}$$

$$- \frac{\sin a \cos a\,(200 \sin a \cos a + 20 \cos^2 a - 20 \sin^2 a)}{(100 \sin^2 a + 20 \sin a \cos a + 1)^2};$$

or,

$$1 - 102 \sin^2 a = 0,$$

$$\sin a = \frac{1}{\sqrt{102}} = .099 \qquad (22)$$

It will be remembered that when r was neglected the angle in this case was imaginary, but as soon as resistance is introduced it becomes definite, since all the power is not being used to exert torque.

Substituting (22) in (21) we have

$$\text{Max. } T = \frac{E^2}{\pi N^2 \omega^2 L} \times 2.5. \qquad (23)$$

Substituting (19) in (21) we have

$$T \text{ for max. } \eta = \frac{E^2}{\pi N^2 \omega^2 L} \times .82 \qquad (24)$$

The maximum torque is about three times the most efficient torque in this case.

Any other assumed set of conditions could be worked out in exactly the same manner that has been used for these two cases.

A NEW HORSEPOWER CALCULATOR.

By Commander U. T. Holmes, U. S. Navy, Member.

Several instruments employing the logarithmic scale in some form have been devised for the mechanical calculation of horsepower. The following explanation refers to one which may be readily constructed on board ship and which will prove a great labor saver where many horsepower calculations are to be made.

Writing the expression for horsepower in the form

$$\text{H.P.} = \frac{P \times R}{k}, \text{ or H.P.} \times k = P \times R$$

we have

$$\log \text{H.P.} + \log k = \log P + \log R.$$

In figure 1 assume a base line AB and draw two parallel lines as AC and BD. On one of these, as AC, construct a scale to represent various values of log P. On the other, construct a similar scale to represent various values of log R. Assume any values of P and R such that $AE = \log P$ and $BF = \log R$. Draw EF and bisect at G. Through G draw GH, parallel to AC and BD. Then

$$GH = \frac{AE + BF}{2} = \frac{\log P + \log R}{2} = \frac{\log \text{H.P.} + \log k}{2}.$$

Lay off $HI = \frac{\log k}{2}$. It is obvious then that G lies at a point such that $IG = \log \frac{\text{H.P.}}{2}$. By using a scale of 1 : 2, with the point I as the zero point, IG may be graduated to represent the H.P. on a logarithmic scale, such that for any values of P and R, falling on their respective scales at E and

F, the corresponding H.P. lies on the scale IG, at a point G where this scale intersects with the mid point of the straight line joining E and F.

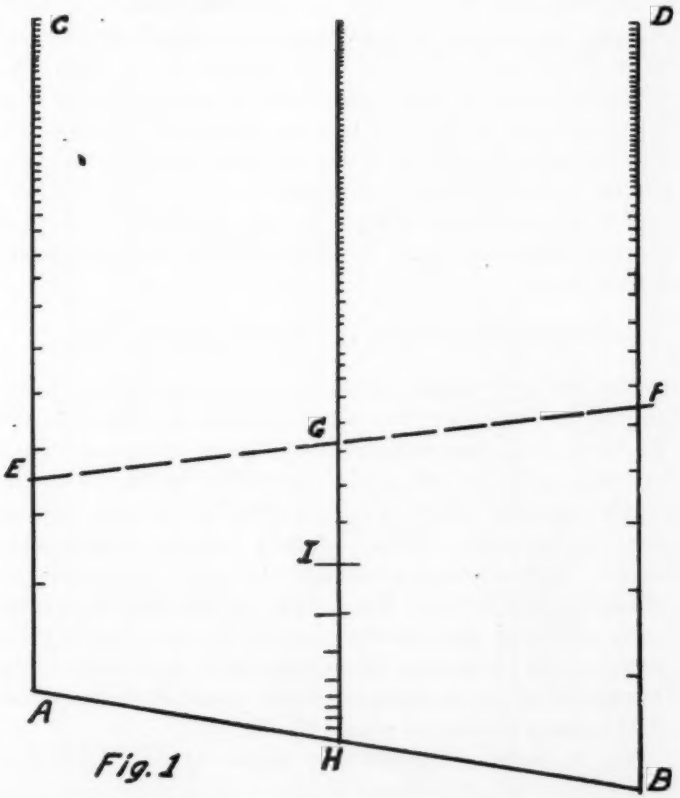


Fig. 1

An instrument constructed in this manner may be adapted for general use by making the scale of H.P. adjustable in a vertical line. The value of HI, or k, corresponding to the particular engine cylinder or dynamometer for which it is desired to use the instrument is then read downward from I and the scale of H.P. set with the proper value of k falling at H. The instrument is then ready for use. When constructed for

use in calculating the indicated horsepower of the various cylinders of an engine, the various values of log k may for convenience be laid off and marked for each end of each cylinder instead of in the form of a graduated scale. In order to make the instrument more compact the base line may also be moved upward or inclined at an angle to AC, BD and HG. The instrument will be capable of greater accuracy if the base line is inclined so that EF becomes horizontal or nearly so. The intersections with the scales will then be sharper and they can be read with greater distinctness.

The above diagram is laid down for a value of $k = 16.8$, corresponding to an engine cylinder 25 inches in diameter and 2 feet stroke.

APPLICATION BY LIEUTENANT COMMANDER JAMES.

The above principles were applied by Lieutenant Commander L. F. James, U. S. N., in devising an instrument for the mechanical determination of the power developed by the various engines in use in the engineering laboratory at the Naval Academy. Each of these engines may be indicated and each is fitted with a brake for shaft horsepower determinations. There are also torsionmeters and other forms of transmission dynamometers. The instrument has been constructed for a particular application to any one of these, but is made large enough to illustrate the application of the method to the calculation of the horsepower of any engine or brake, where the horsepower does not exceed 15,000.

Fig. 2 shows a diagrammatic outline of this instrument while a photograph is shown in Fig. 3. The instrument is described by Lieutenant Commander James as follows:

DESCRIPTION OF THE APPARATUS.

The body of the board consists of several seasoned planks, one inch thick, tongued and grooved together on their edges, and stiffened at the back by several stout pieces secured to the board by screws. The flat face of the board is covered with

sheet drawing paper pasted on. This insures a smooth surface and gives a good backing for the sliding scales. Several scales are fitted on the face of the board, and are properly marked and lettered for convenient reference. These are

GENERAL REPRESENTATION OF MECHANICAL POWER CALCULATOR.

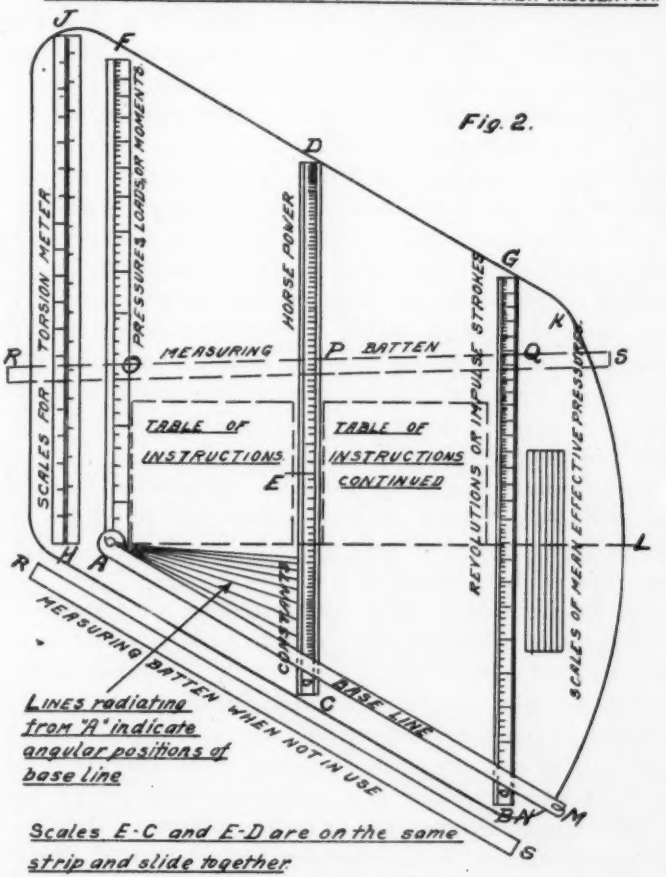


Fig. 2.

made of thin wooden strips, and are also covered with sheet drawing paper on which the lines of graduation are drawn. Scales *BG*, *EC* and *ED*, are capable of vertical adjustment between small wooden guides, and are fitted at their ends with

brass finger clips, which serve to adjust them in the required position while measurements are being taken. All the other scales are permanently fixed in position. It may here be stated that the three principal working scales, *AF, BG, ECED,* are logarithmic scales, and are used in every computation of every nature to which the instrument applies. The remaining scales are used only in special cases. The adjustable base line, *AM,* is a metal straight-edge strip, pivoted at *A,* and is capable of adjustment through an arc of 30 degrees above and 30 degrees below the horizontal line *AL,* the end *M* being guided along the circular edge *KLN.* A screw clamp at *M* serves to hold the base line in any desired position. Its exact position, for best results, depends upon the particular computation under consideration. Several of these positions are clearly marked on lines radiating from the base-line pivot point *A.* The measuring batten, *RS,* is a detached wooden straight-edge strip used for noting values on scale *ED,* corresponding to given values on the two adjacent working scales, *AF* and *BG.* When not in use the batten is kept in a small rack, provided for the purpose, at the bottom of the board.

In the construction of the instrument the scales marked *AF* and *BG* (Figs. 2 and 3) were actually laid off directly from the scale on a 20-inch straight slide rule. Scales *EC* and *ED* were laid off from a 10-inch slide rule.

On the right-hand side of the board there are drawn several scales, so graduated that the mean effective pressures of the H.P. and I.P. cylinders of the second laboratory triple-expansion engine and the mean effective pressure of the H.P. cylinder of the second laboratory compound engine may in each case be converted into equivalent mean effective pressures of their respective L.P. cylinders. These scales are clearly marked, and they may be used to advantage when it is desired to compute, in one operation, the total I.H.P. of one of these engines.

The fixed parallel scales on the left-hand side of the board show the values of moments in the Denny-Johnson torsion-

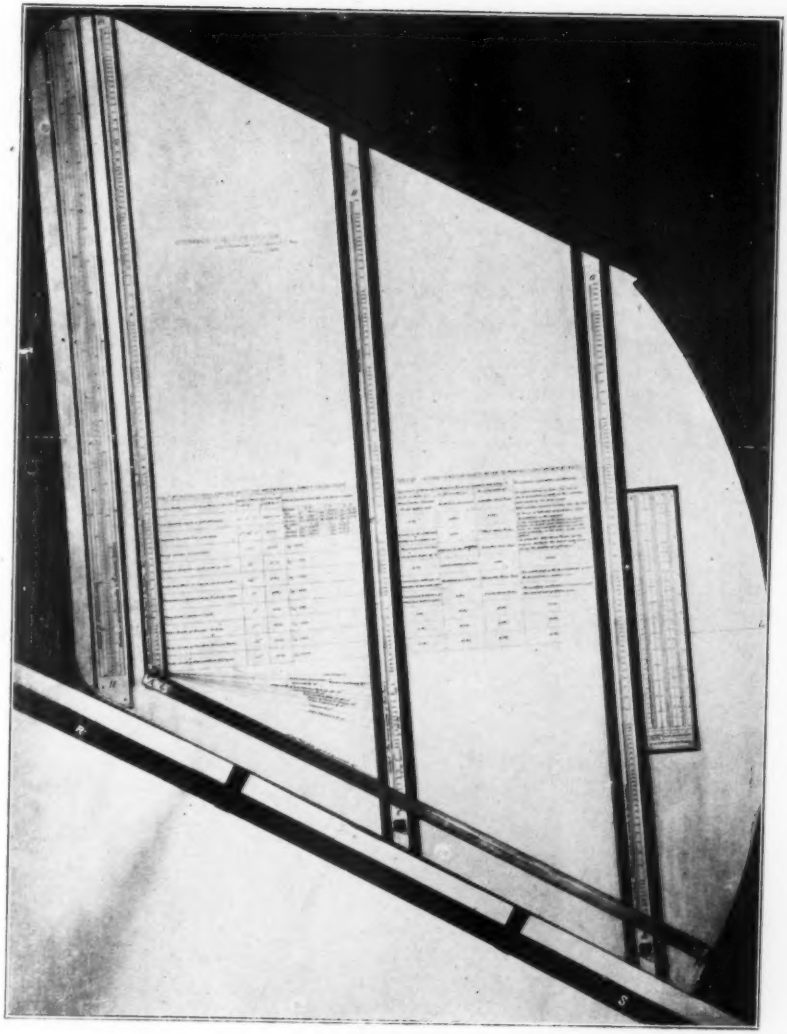


Fig. 3.

meter shaft, corresponding to angular deflections of the shaft as measured, in inches, by the torsionmeter.

The tables of instructions shown on the face of the instru-

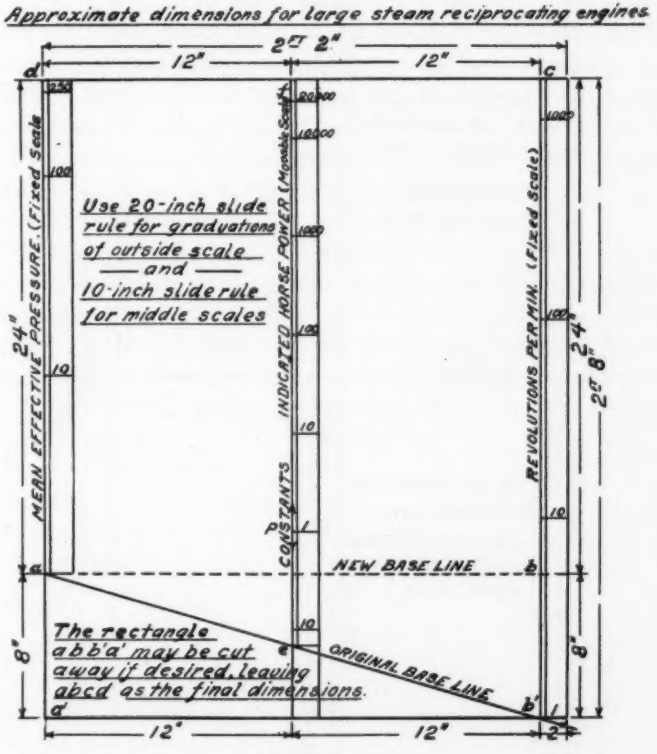
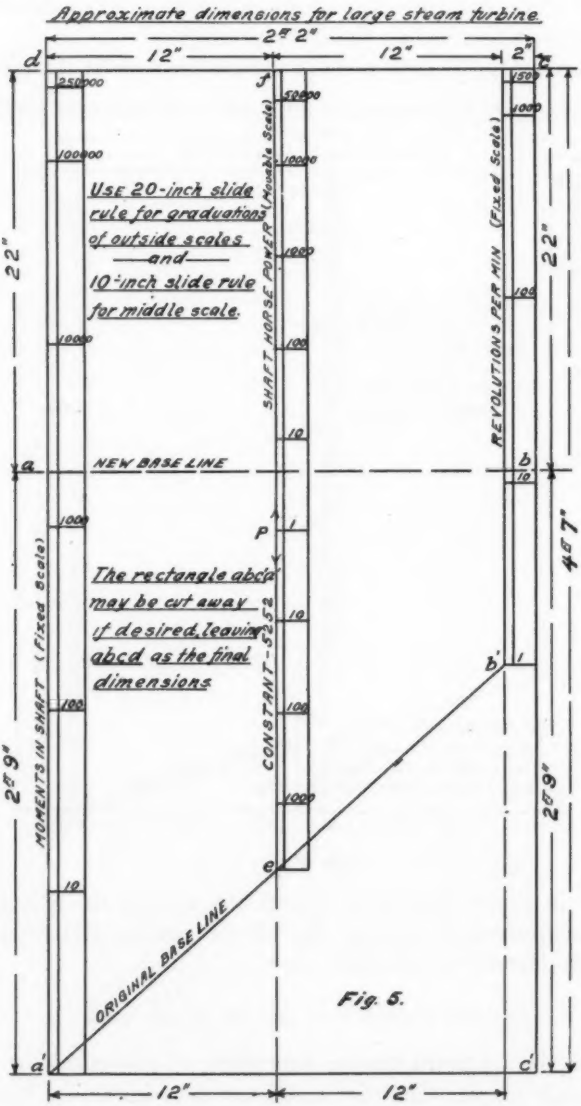

Approximate dimensions for large steam reciprocating engines.
2FT 2"
12"
12"
MEAN EFFECTIVE PRESSURE. (Fixed Scale
INDICATED HORSE POWER (Movable Scale)
REVOLUTIONS PER MIN. (Fixed Scale)
Use 20-inch slide rule for graduations of outside scale — and — 10-inch slide rule for middle scales
CONSTANTS
NEW BASE LINE
ORIGINAL BASE LINE
The rectangle abb'a' may be cut away if desired, leaving abcd as the final dimensions.
24"
8"
2FT 8"

Fig. 4.

ment in Fig. 3 give the constants and explain the setting of the instrument for each of the various engines and dynamometers installed in the laboratory.

INSTRUMENTS FOR USE ON BOARD SHIP.

For use on board ship an instrument of this character will be much simpler than that made for the engineering laboratory. Fig. 4 represents such an instrument adapted for use


Approximate dimensions for large steam turbine.
2ft 2"
12"
12"
2"
22"
2ft 9"
4ft 7"
Use 20-inch slide rule for graduations of outside scales
and
10-inch slide rule for middle scale.
NEW BASE LINE
The rectangle abc'a' may be cut away if desired, leaving abcd as the final dimensions.
ORIGINAL BASE LINE
MOMENTS IN SHAFT (Fixed Scale)
CONSTANT - 5.52
SHAFT HORSE POWER (Movable Scale)
REVOLUTIONS PER MIN (Fixed Scale)
Fig. 5.

with a large reciprocating engine, while Fig. 5 shows a similar instrument adapted for use with a large turbine. Both of these are as proposed by Lieutenant Commander James. In each the portions of the different scales that are unnecessary have been discarded, making the instrument more compact or enabling the scales to be made larger. In cutting away at the bottom care should be exercised to select points on the outside scales slightly below the smallest values of pressures or moments and revolutions that are likely to obtain; also to take the same precaution in regard to moving the constant point up along the middle scale.

These instruments may be readily constructed on board ship. The work will be greatly facilitated by transferring the markings on a straight slide rule if such an instrument is at hand. A 20-inch slide rule for the outside scales and a 10-inch rule for the middle scale will produce an instrument that will give results accurate within the limits of error of the horsepower data.

BOILER COMPOUNDS.

By Lieutenant Commander Frank Lyon, U. S. Navy, Member.

There are now on the market many chemical compounds for treating boiler water. The claims made for these compounds are many and varied. Listening to the agent for almost any one of them, one would be tempted to believe that it would do anything in the cleaning and scale-removing line, even to the absurd and the impossible. One agent claims that his compound has the peculiarity of changing the form of the scale-forming molecules in the water from the hook-shaped to spherical. These molecules, being round, cannot stick on metallic surfaces, and therefore cannot form scale. The writer unfortunately cannot verify the claim.

In the summer of 1910 it became a part of the writer's duties to examine, test and report upon some of these boiler compounds in an effort to find that best suited to naval use. The literature upon the subject is very meager, and it devolved upon the writer to devise a method of making these tests. The plan upon which he has worked and the principles involved are given below.

The perfect boiler compound for naval or marine use will be one fulfilling the following chemical requirements:

(a) It must render the water in the boiler non-corrosive at any temperature to which it may be subjected.

(b) It must hold in suspension, or preserve in the colloidal form, all of the salts in the water that would otherwise be precipitated as scale, whether such precipitation be by the action of heat or by that of any of the chemicals used in the compound.

(c) It must render the treated water no more liable to foam

or prime than distilled water would be under the same conditions.

(d) It must be composed of chemicals that are safe to store, that do not deteriorate materially with age, and that are non-explosive and non-inflammable. In other words, the compound must be such that it requires no particular care in stowage and handling.

(e) Some one constituent must be such that its strength in the water (its concentration) can be easily measured by some simple chemical measuring device.

In brief: The compound must render the water in the boiler non-corrosive and non-scale forming, it must be easy to care for and use, safe for stowage on board ship, and the net effect of its constituents must be such as will not increase the surface tension.

The following is the series of tests suggested to the writer's mind to which all such compounds should be subjected:

(A) Chemical;
(B) Corrosion;
(C) Scale removal;
(D) Priming.

CHEMICAL TESTS.

(A) Chemical tests are conducted as follows: As soon as a compound is received, in liquid form, samples drawn from near the top, near the middle, and near the bottom of the receptacle, are poured together and well shaken in a large bottle. If in powdered form samples are taken from the containers in the same way and mixed in a glass receptacle. A fair sample having been taken it is then turned over to the station chemist for (1) qualitative and quantitative analysis, (2) determination of the specific gravity in concentrations containing one part by volume in 10, 100, and 1,000 parts of distilled water, and (3) determination of the boiling point at atmospheric pressure of the same concentrations as used in (2). From the analysis its safety in storage, handiness and inflammability are judged.

CORROSION.

(B) Tests are then made to determine the corrosiveness of the compound in distilled water and in Severn River water containing 450 grains of chlorine per U. S. gallon, at atmospheric temperatures and at the temperature of 421 degrees F., corresponding to an absolute steam pressure of 315 pounds. If the compound is in liquid form, 200 c.c. of different concentrations are made up and placed in similar glass jars. Pieces of boiler-plate steel are immersed in these to a depth of two inches below the surface of the solution. These test pieces are all from the same piece of boiler plate, and are filed bright all over; their dimensions are as follows: ¾ inch × ¾ inch × $^3/_{10}$ inch.

The jars are then so placed that all are subject to the same temperature, light and draft influences and the highest concentration in which corrosion shows is noted:

This is accomplished as follows (1) in distilled water:

: A : B : C : D : E : F : G: H:

In glass jar "A" 200 c.c. of the compound as analyzed is placed.

In jar "B," one part of compound by volume in 10 of solution.

In jar "C," one part in 100.

In jar "D," one part in 1000.

In jar "E," one part in 10000.

In jar "F," one part in 100000.

In jar "G," distilled water alone.

(2) In Severn River water, containing 450 grains of chlorine per U. S. gallon:

In jar "A," one part of compound by volume in 10 of solution.

In jar "B," one part in 100.

In jar "C," one part in 1000.

In jar "D," one part in 10000.

In jar "E," one part in 100000.

In jar "F," Severn River water alone, the same water with which the concentrations are made.

The tops of the jars are left open on all of the above concentrations. After 24 hours of immersion the test pieces are examined. Suppose there was no corrosion on "A" and "B" of (1), or on "A" of (2), and there was corrosion on all of the others. Then there would be made up a quantity of the same concentration as "B" in (1) and "A" in (2), concentrations between "B" and "C" of (1), and between "A" and "B" of (2), as follows:

In (1):

200 c.c. of "B"
180 c.c. of "B" and 20 c.c. distilled water = .9 "B"
160 c.c. of "B" and 40 c.c. distilled water = .8 "B"
140 c.c. of "B" and 60 c.c. distilled water = .7 "B"
120 c.c. of "B" and 80 c.c. distilled water = .6 "B"
100 c.c. of "B" and 100 c.c. distilled water = .5 "B"
80 c.c. of "B" and 120 c.c. distilled water = .4 "B"
60 c.c. of "B" and 140 c.c. distilled water = .3 "B"
40 c.c. of "B" and 160 c.c. distilled water = .2 "B"
20 c.c. of "B" and 180 c.c. distilled water = .1 "B"

(The last is the same as concentration "C.")

In (2):

200 c.c. of "A"
180 c.c. of "A" and 20 c.c. of Severn River water = .9 "A"
(450 gr. chlorine per U. S. gallon.)
160 c.c. of "A" and 40 c.c. of Severn River water = .8 "A"
140 c.c. of "A" and 60 c.c. of Severn River water = .7 "A"
120 c.c. of "A" and 80 c.c. of Severn River water = .6 "A"
100 c.c. of "A" and 100 c.c. of Severn River water = .5 "A"
80 c.c. of "A" and 120 c.c. of Severn River water = .4 "A"
60 c.c. of "A" and 140 c.c. of Severn River water = .3 "A"
40 c.c. of "A" and 160 c.c. of Severn River water = .2 "A"
20 c.c. of "A" and 180 c.c. of Severn River water = .1 "A"

(The last is the same as concentration "B.")

Test pieces, made in the same way and from the same plate as those described in paragraphs 9 and 10 preceding, are then

immersed in these jars, and the concentration next above the one in which corrosion begins in 24 hours, in each case, is noted and is considered to be the non-corrosive concentration of the compound in the kind of water in which the solution is made.

Concentration in distilled water

B : .9B : .8B : .7B : .6B : .5B : .4B : .3B : .2B : .1B or C

Concentration in Severn River water:

A : .9A : .8A : .7A : .6A : .5A : .4A : .3A : .2A : .1A or B

Suppose corrosion shows within 24 hours on the pieces in concentrations underscored. Then concentration .8B in distilled water and .4A in Severn River water are the non-corrosive concentrations of this compound in the waters used, respectively.

If the compound gives an alkaline reaction in water its strength can be measured by a very simple chemical test, as follows: Measure a 50 c.c. sample in a 100 c.c. measuring cylinder, drop three or four drops of standard neutrality indicator into the sample and run $^1/_{10}$th normal sulphuric acid into it until the faint pink of the methyl orange in the indicator is just shown throughout the sample after shaking well. Each c.c. of $^1/_{10}$th normal acid used indicates $^1/_5$th of 1 per cent. of normal alkaline strength.

Having obtained the non-corrosive concentrations of the compound in distilled water and in water containing 450 grains of chlorine per U. S. gallon, the alkaline strength, in percentage of normal, is measured and recorded. The alkaline strength of compounds in any water that is just non-corrosive will be practically the same, varying from 2.4 to 3 per cent. normal alkaline.

All of the above jars are allowed to remain for 30 days in the open, and are examined daily to see if the concentration is being weakened by the absorption of carbon dioxide from the air. If the concentration is so weakened from contact with the air the higher concentrations will be gradually weakened, and the pieces in .8B and .4A will sooner or later begin to corrode; then .9B and .5A, and the others above successively. When

the pieces above the originally non-corrosive solution first show rust their alkaline strength, if immediately measured, will show practically the same degree of normal alkaline strength as did the one next below the non-corrosive concentration obtained after the first 24-hour test.

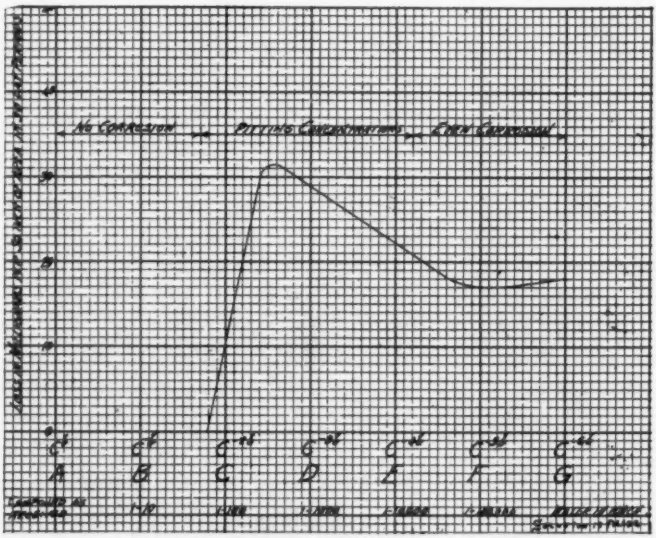
Now, having determined the non-corrosive concentration of the solution in two waters at atmospheric temperatures, these concentrations are made in each of the above waters, and one liter of each is placed in a section of a 4-inch boiler tube, and some test pieces similar to the ones used above are immersed in the solution. The tube is then capped and subjected to a temperature of 421 degrees F. for 48 hours, when it is removed and examined to see if the tube, caps or test pieces show any signs of corrosion. In no case has the writer yet found that a solution non-corrosive at atmospheric temperatures was corrosive at a temperature of 421 degrees F.

In all cases it has been found that the concentrations just below the non-corrosive one show pitting. As, for example, in distilled water with the compound in mind, no corrosion was shown in "A" or "B;" pitting was shown in "C," "D" and "E," and apparently even corrosion in "F" and "G." In (1) of the same compound no corrosion was shown on "B," .9B and .8B; pitting was shown on all of the other fractional concentrations of "B." If the compound is one that loses strength by contact with the atmosphere, then, as the strength is lost, first .8B, then .9B, etc., begin to show rust in spots, and when the spots are removed the pitting shows up very plainly.

If the concentration loses strength by contact with the air less rapidly than it is concentrated by loss of water evaporated, then the corrosion in .7B, then .6B, etc., stops; and, if the pieces are removed from time to time, and the rust spots are washed off, these spots will not appear again in the strengthened solution unless water be added to dilute the solution.

It may be stated here that in all compounds in which a non-corrosive concentration has been prepared, as well as in calcined sodium carbonate, di-sodium phosphate, caustic soda and calcium hydroxide, the non-corrosive concentration shows between 2.4 and 3 per cent. normal alkaline strength.

If the test pieces in jars "A," "B," "C," "D," "E," "F" and "G" are carefully measured and weighed on a chemical balance before they are immersed, and then taken out of the concentrations after an immersion of 20 or 30 days, washed and brushed with a hair brush, and carefully weighed, the results in all compounds and in all chemicals with which a non-corrosive solution can be made are such that the characteristic curve will be as shown in Curve 1 appended, marked A, in which the ordinates are losses in units of weight per unit of area per unit of time, and the abscissae are concentrations.



Curve 1.

If after the compound is added to the water a sludge or precipitate is thrown down, the water is filtered and the precipitate re-dissolved in distilled water. Pieces of weighed steel, as above, are immersed in this solution and in the same amount of distilled water, the jars are left open, placed side by side, and the pieces are allowed to remain for 30 days. They are then cleaned and re-weighed, and the losses in units of weight

per unit of area per unit of time are calculated and compared. If there is nothing in the compound that is thrown out when added to a water that will increase the corrosiveness of the water, the average loss in each of the two sets should be practically the same.

All corrosive tests are repeated two, five, or, in some instances, ten times, and the average results are used in drawing conclusions.

If the compound is in powdered or solid form the operation of testing is exactly similar to the above, except in making up the base solution, which is as follows:

Fifty grams of the compound are dissolved in distilled water, and 50 grams in the Severn River water, containing 450 grains of chlorine per U. S. gallon; and these solutions are brought up to one liter. Test speciments of bright steel are immersed in each of these solutions, and after 24 hours are examined carefully for any signs of corrosion. If corrison is shown these concentrations are discarded and others containing 100 grams of the compound per liter are made and tested in the same manner. This is continued until a non-corrosive base solution is made or the saturated concentration is reached. If a non-corrosive concentration is reached it is used as the base concentration "A," and the concentrations "B," "C," "D," "E" and "F" are made by diluting the base in exactly the same manner as if the compound had been received in liquid form.

After this preliminary work is done the non-corrosive solution is made up, and a small fire-tube boiler of gunboat type is filled to steaming level after test pieces of boiler-plate steel have been placed in it, as follows: Two laid across the copper tubes at right angles to their length near the ends of the tubes; one on the bottom of the boiler at each end, and one laid flat on top of the fire box.

The boiler is an old iron boiler, removed from a captured Spanish steam launch after the Spanish War. It holds 55 gallons of water up to steaming level and 75 gallons when completely filled.

The test pieces are from the same plate as those used in the preliminary test, and are 3 inches × 1 inch × $^{3}/_{10}$ inch, filed bright, measured and weighed. The non-corrosive concentration in fresh water from the well is first used. Fires are started and a steam pressure of 180 pounds gage pressure is maintained for ten days. The degree of concentration is ascertained by drawing water from the boiler daily, and measuring its alkaline strength. If it is below that of the non-corrosive concentration more of the compound is added, until the strength shows equal to or above that of the non-corrosive concentration. During the fresh-water test the boiler is fed with fresh water from the station well, and the steam is used for operating various pumps. After ten days the fire is allowed to die down, the boiler is emptied and opened, and the boiler and test pieces examined for corrosion. The test pieces are washed and brushed and re-weighed. Any loss by corrosion is shown by the loss of weight.

In making this test with Severn River water the boiler is operated and fed with Severn River water until the chlorine content shows 2,000 grains per U. S. gallon. Fires are then allowed to die out, the boiler is opened, and the test pieces placed as above; the compound is added until the alkaline strength shows, by test, the same as the non-corrosive solution in the same water. The boiler is then closed and fires started. It is run for ten days with the chlorine content maintained at 2,000 grains per U. S. gallon by use of the bottom blow.

The alkaline concentration is ascertained by measuring the strength of water drawn from the boiler daily, and the strength is kept at or above that of the non-corrosive concentration in Severn River water by such addition of the compound as may be found necessary. The other details are the same as those observed when testing with fresh water. In each of these tests the compound, if in powdered or solid form, is dissolved and the solution is run into the boiler. The amounts of the compound by weight to make the water of non-corrosive strength, and keep it so for ten days, are recorded in each case.

From the above data the weight of compound necessary to

make a ton of each of the two kinds of water used non-corrosive is calculated.

The data obtained from the tests of different compounds obtained in the above manner are compared in an effort to find the cheapest and best compound in respect to the non-corrosive action alone.

SCALE REMOVAL TEST.

(C) The non-corrosive concentration having been located, and its strength in percentage of normal alkalinity measured and recorded in Severn River water, containing 450 grains of chlorine per U. S. gallon, a liter of the non-corrosive concentration is made in this water and placed in a section of 4-inch boiler tube capped at the lower end. The tube and cap are made bright before the liquid is put in it. This tube is then placed over a gas burner and the solution evaporated to dryness, and the scale baked on for one hour after the tube is dry; the tube is then examined for scale. When the tube has cooled to the temperature of the atmosphere a liter of the same water is poured into it and allowed to set for four hours. It is then poured out and the tube re-examined. If the tube and cap are clean the compound is temporarily rated as excellent.

A bucket of the non-corrosive concentration is then made, and a section of an old boiler tube containing hard scale is placed in it. It is left open to the atmosphere. This tube is examined daily for ten days, and the state of the scale noted each day.

The above preliminary work having been done, the practical part of the scale-removal test is accomplished in the same small boiler as is used for the corrosion tests noted above, and while the corrosion tests are in progress.

Before starting the corrosion test with fresh water the boiler is run for five days at a chlorine concentration of from 2,500 to 3,500 grains of chlorine per gallon. The boiler is filled with Severn River water at first and fed with the same water while precipitating the scale. Fires are allowed to die out and the boiler blown down; the boiler is then opened and examined.

Some scale is broken off the crown sheet and tubes in a few places, and samples taken for comparison with samples of scale to be broken off after the ten-day test. The scale is removed from the crown sheet and tubes at places where test pieces for the corrosion test are to be placed. The boiler is then closed, filled to steaming level with fresh water, made non-corrosive, and fires are started. A pressure of 180 pounds by gage is maintained for ten days. Fires are then allowed to die out; the water is blown out; the boiler opened and examined. Scale is broken off adjacent to where scale was broken off before the test, and the two specimens are compared. The spot from which the first specimen of scale was removed is examined to see whether new scale has formed.

The same sequence of details is carried out when making the test using non-corrosive solution of Severn River water; the scale-removing test and the corrosion test occurring coincidently and in the same boiler.

From these tests it can be ascertained whether or not the non-corrosive solution of the compound permits scale to form, and whether or not it removes scale previously formed.

PRIMING TESTS.

(D) The priming tests have so far been made in a glass receptacle connected to a condenser, by boiling distilled water in the receptacle over a bunsen burner. A few drops of caustic soda are placed in the receptacle, and water drawn from the condenser is tested for alkali (1st) just after boiling has begun, and (2d) after it has been boiling hard for 20 minutes. The height of the water is taken before the burner is lighted, and the height of the top of the visible foam just after boiling begins, and also after it has been boiling hard for 20 minutes. The same amount of the non-corrosive solution of the boiler compound in distilled water is then placed in the receptacle, and the above operations are carried out. The conditions are made as nearly similar as possible by using the same receptacle, same amount of solution, same gas pressure, same gas-cock opening to burner, and with the

burner in the same location as when testing with distilled water alone.

The same operation is carried out with a non-corrosive solution of the compound in Severn River water carrying 450 grains of chlorine per gallon.

The comparative data are very interesting, even if not exact.

An apparatus is now being prepared by means of which the temperature of the water can be kept constant at 420 degrees F., and the steam at different heights above the water level drawn through a separating calorimeter, and its quality at these heights ascertained. The height of the water in the apparatus will be kept at a constant level.

HOW TO USE THE COMPOUND.

Any boiler compound that will show excellent results under the above system of tests can be made to work in any boiler with any water, if the boiler and water are properly treated. Many such compounds are condemned on first trial with boilers in actual use because they do their work better than expected, and the man in charge of the plant fails to do his.

When contemplating the use of a compound the man in charge of a boiler must first understand the nature of the treatment, the results to be obtained, and the work of the fireman in conjunction with the treatment necessary to obtain the desired results.

Before putting a new boiler in operation it should first be boiled out well for at least 24 hours with a strong solution of the compound, using the bottom and surface blows for about two minutes each hour; using distilled water, if possible, to make up the loss of feed in the boiler, and adding more compound after each blow. Before starting the use of any compound in an old boiler the same preliminary details should be followed. The reasons for the preliminary work are:

(1) When putting a new outfit of boilers into operation it is always found that there is a great amount of greasy scale and dirt thrown down, even when good distilled water is used for boiler feed.

(2) In an old boiler which is considered to be as clean as possible, a good boiler compound will cut a very considerable amount of grease and scale from the apparently clean surfaces.

(3) In an old boiler which has not been cleaned, the action of the compound would first be to form colloidal solutions with any scale-forming ingredients that are in the water, and the excess of compound then acts on the scale and grease attached to the boiler surfaces, loosening them from the surfaces and throwing them down onto the lower surfaces of the boiler, in time dissolving these impurities.

If the boiler is boiled out, using good water with the compound, much of this scale and grease will be loosened and a great part of it can be removed through the blows. After boiling and blowing for 24 hours the fires should be allowed to die out, and before all of the pressure is off the boiler all of the water should be blown out. The lower manhole and handhole plates should then be taken off and all loose scale raked out of the bottom tubes, lower headers and lower drums. If this is not done the loose scale and greasy solution may do the boiler harm.

The boiler should then be closed, pumped full of non-corrosive solution of the compound, and given a hydrostatic test for tightness. If tight, the water should be run down to steaming level, and the boiler is then ready for regular operation.

When fires are started to put the boiler in regular operation the bottom blow should be used freely as steam rises. When steam is up to working pressure the strength of the compound should be measured and brought up to that of a non-corrosive solution, if it is not already there. The saturation should then be taken with the ordinary salinometer pot and hydrometer bulb, recorded and considered the base saturation. The strength of the solution and the saturation should be taken daily. The strength of the solution as drawn from the boiler should be brought up to that of a non-corrosive solution whenever it is found below that strength, and the bottom blow should

be used whenever the saturation is found $^1/_{32}$ above that of the base, as shown by the ordinary marine hydrometer.

If this method is carried out for a short period of time the boilers will be cleaned.

By keeping an accurate record of the amount of decrease of strength of solution daily a fairly accurate deduction can be made as to how much additional compound is needed each day so long as the character of the feed water is not changed. If the constituents of the compound are non-volatile at the maximum temperature to which the boiler water is subjected (as they surely should be) the strength of the compound will remain constant if the feed water is pure, the boiler has no leaks, the blows are not used, and if the boiler does not prime; that is, if the boiler was clean to begin with. The loss of strength is due to the constituents of the compound combining chemically with those of the dissolved scales and with those in the feed water with which they react, to the water lost by leaks in the boiler, the use of the blows, and to the water carried over in priming; make up feed being assumed to be fresh.

If the proper precautions of boiling the boiler out before beginning the regular use of the componud, and of using the blows properly, are not carried out, a boiler compound having many good qualities may be condemned on its first trial merely because it is doing its work properly and consistently, when, if given a fair trial, it would be considered a pronounced success.

The writer has measured the alkaline strength of the non-corrosive solutions of the compounds for the reason that all compounds and all chemicals with which he has experimented, that stop corrosion entirely, except the chromate solutions, give an alkaline reaction, and require the same amount of $^1/_{10}$th normal sulphuric acid to make a 50 c.c. sample show an acid reaction with the standard neutrality indicator.

In the opinion of the writer the only way to properly treat boiler water is to measure the strength of the solution in water drawn from the boiler and treat it in accordance there-

with. Any rule of treating water other than by measuring the strength of the solution as drawn from the boiler is dangerous, for the reason that if the character of the feed water changes at any time a different amount of compound will be needed with each character of feed water.

The constituents in the compound should be so arranged that among the non-corrosive constituents are included enough of the non-scale forming and non-priming ones to automatically make the perfect compound in all characters of water when the solution is made non-corrosive.

One thing that has been proved to the writer is, that unless a compound is used properly it is better let alone.

With the alkaline solutions used in making corrosion tests, with the exception of quick lime, the writer has been able to make non-corrosive solutions in distilled water, surface-well water, artesian-well water, Severn River water, and in sea water. He has been unable to get a non-corrosive solution in sea water and in Severn River water with lime, even with saturated solutions.

DANGEROUS COMPOUNDS.

Due to the fact that many compounds have been devised for the purpose of removing scale without regard to the corrosive element of the compound, the writer earnestly recommends that all compounds be tested for their corrosiveness before they are used. The simple method used by the writer requires a measuring glass and a few clean glass bottles or fruit jars.

It is learned, from an examination of the Patent Office records, that there are boiler compounds, guaranteed to remove scale, of which hydrochloric acid is the base. Undoubtedly such a compound will remove the scale, also everything metallic with which it comes in contact.

There are found in some periodicals articles giving experience with graphite in boiler water, in which it is proved that graphite is an excellent scale remover. Graphite is a scale remover for the same reason that hydrochloric acid is. That

is, it corrodes the metal underneath the scale and frees the scale from the metallic surfaces.

The writer has found that steel boiler plate immersed in distilled water containing graphite in contact with the metal corrodes from 200 to 400 per cent. faster than specimens from the same plate immersed in the same water without the graphite, all other conditions remaining the same. The amount of corrosion varies with the purity of the graphite and with the amount of it in contact with the metal.

DESCRIPTION AND TRIALS, U. S. TORPEDO BOAT DESTROYER *PATTERSON.*

By W. B. Robins, Associate.

Torpedo-boat destroyer No. 36, the *Patterson*, is one of five destroyers authorized by Act of Congress approved March 3, 1909.

The contract for this vessel was signed June 14, 1909, and called for delivery within 24 months, the contractors being The William Cramp & Sons Ship and Engine Building Company, Philadelphia, Penna. The *Patterson* was launched April 29, 1911, and was delivered October 7, 1911, at the Navy Yard, Philadelphia.

The general requirements of the contract were as follows:

Displacement .....About 742 tons.
Speed on four-hour full-speed trial.....29½ knots.

TRIALS.

(1) A progressive trial over a measured-mile course for standardizing the screws, about twenty runs to be made over the course.

(2) A four-hour full-speed (29½ knots) trial, air pressure not to exceed 5 inches of water, steam pressure at high-pressure turbine not to exceed 240 pounds above atmosphere.

(3) A four-hour 27½-knot trial.

(4) A four-hour 25-knot trial.

(5) A four-hour 20-knot trial.
(6) A four-hour 16-knot trial.
(7) A four-hour 12-knot trial.

The contract price was $637,000.00, of which $367,000.00 was allotted for machinery.

GENERAL DESCRIPTION OF THE VESSEL.

Hull.

The general arrangement of decks, bulkheads, etc., is the same as that of the *Ammen,* described in the May, 1911, number of the JOURNAL, and the principal hull dimensions are as follows:

Hull Data.

Length between perpendiculars, feet and inches	289–00
over all, feet and inches	293–10½
on load water line, feet and inches	289–00
Breadth, molded, extreme, feet and inches	26–04½
on load water line, feet and inches	26–00½
Depth, molded, main deck at side, midship section, ft. and in	16–04¾
Draught, normal, above bottom of keel, feet and inches	8–04
Displacement, normal, at 8 ft. 4 ins., draught, tons	742
per inch at 8 ft. 4 ins. draught, tons	12
Coefficient of fineness, block	0.408
Capacity of reserve feed-water compartments, tons	14.69

Machinery.

The propelling machinery consists of Parsons steam turbines and White-Forster oil-burning water-tube boilers, with the necessary auxiliaries. The arrangement of turbines is the five-turbine, three-shaft arrangement usually adopted for destroyers with Parsons turbines; viz: main high-pressure turbine on center shaft, H.P. cruising and one L.P. on one wing shaft, and I.P. cruising and one L.P. on the other wing shaft; each L.P. turbine having a backing turbine inclosed in its after end.

Turbine Data.

Expansion.	.....	Ahead. H.P.C.	Ahead. I.P.C.	Ahead. M.H.P.	Ahead. L.P.	Astern.
1	Diameter of cylinder, inches	30⅜	30⅜	32⅜	46⅜	31½
1	Length of cylinder, this diameter, inches	16½	16⅜	13½	7	9⅜
1	Rows of blading	18	16	10	5	8
1	Length of blades, inches	0⅜	0⅞	1½	1½	0¾
1	Depth or thickness of caulking sections, ins.	0¼	0¼	0¼	0¼	0¼
2	Diameter of cylinder, inches	31	31½	34	48	32½
2	Length of cylinder, this diameter, inches	17½	21¾	14⅞	7½	11½
2	Rows of blading	18	16	10	5	8
2	Length of blades, inches	0½	1½	2½	2½	1⅜
2	Depth or thickness of caulking sections, ins.	0¼	0¼	0¼	0¼	0¼
3	Diameter of cylinder, inches	31⅜	32	35⅜	49⅜	35
3	Length of cylinder, this diameter, inches	17⅜	20½	17	7⅜	14¾
3	Rows of blading	18	16	10	5	8
3	Length of blades, inches	0 1⅛	1½	2⅞	2⅜	2⅜
3	Depth or thickness of caulking sections, ins.	0¼	0¼	0 5/16	0¼	0 5/16
4	Diameter of cylinder, inches	...	...	38	52	35
4	Length of cylinder, this diameter, inches	...	...	18¼	8¼	15
4	Rows of blading	...	...	10	5	8
4	Length of blades, inches	...	...	4½	4½	2⅜
4	Depth or thickness of caulking sections, ins.	...	...	0⅜	0¼	0 5/16
5	Diameter of cylinder, inches	...	...	...	54	...
5	Length of cylinder, this diameter, inches	...	...	...	8	...
5	Rows of blading	...	...	...	4	...
5	Length of blades, inches	...	...	...	5½	...
5	Depth or thickness of caulking sections, ins.	...	...	...	0⅜	...
6	Diameter of cylinder, inches	...	...	...	58	...
6	Length of cylinder, this diameter, inches	...	...	...	8½	...
6	Rows of blading	...	...	...	4	...
6	Length of blades, inches	...	...	...	7⅜	...
6	Depth or thickness of caulking sections, ins.	...	...	...	0⅜	...
7	Diameter of cylinder, inches	...	...	...	58	...
7	Length of cylinder, this diameter, inches	...	...	...	8	...
7	Rows of blading	...	...	...	4	...
7	Length of blades, inches	...	...	...	7⅜	...
7	Depth or thickness of caulking sections, ins.	...	...	...	0⅜	...
8	Diameter of cylinder, inches	...	...	...	58	...
8	Length of cylinder, this diameter, inches	...	...	...	8	...
8	Rows of blading	...	...	...	4	...
8	Length of blades, inches	...	...	...	7⅜	...
8	Depth or thickness of caulking sections, ins.	...	...	...	0⅜	...

Diameter of rotor drums: H.P.C., 30 inches; I.P.C., 29 inches; M.H.P., 29⅜ inches; L.P., 43⅜ inches.

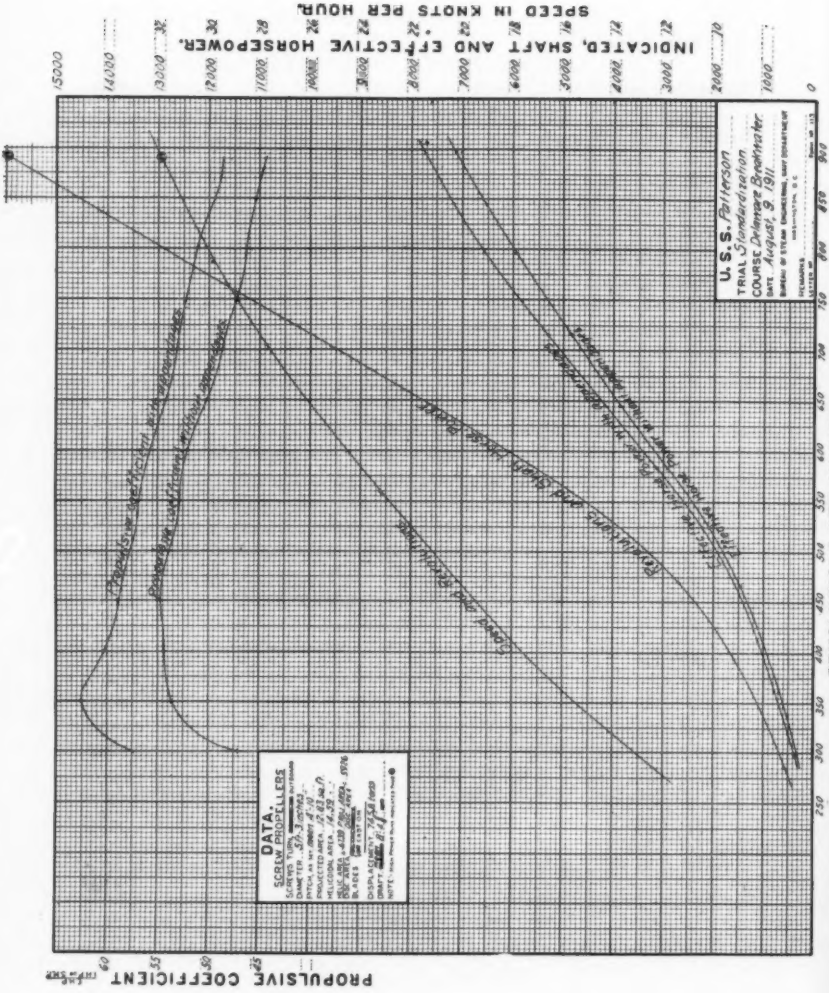
Shafting and Bearings.

H.P. rotor shaft, forward, diameter at bearings, inches 07
of hole, inches..... 03
after diameter at bearings, inches..... 07
of hole, inches..... 03½

L.P. rotor shaft, forward, diameter at bearings, inches	07
of hole, inches	03
after, diameter at bearings, inches	07
of hole, inches	03½
Line shaft, diameter, inches	06¾
of hole, inches	03½
Stern-tube shaft, diameter, inches	06¾
of hole, inches	03½
Propeller shaft, diameter, inches	06¾
of hole, inches	03½
Total length of shafting, including rotor:	
Starboard, feet and inches	73–11 3/16
Center, feet and inches	99–02¾
Port, feet and inches	73–01 3/16
Rotor-shaft bearings:	
Number of, each turbine	2
Length, H.P., forward, inches	07
after, inches	07
L.P., forward, inches	12
after, inches	12
cruising, forward, inches	06½
after, inches	06½
Thrust collars on shaft, H.P. and L.P.:	
Number of	13
Thickness, inch	00 9/16
Space, between inch	00 11/16
Outside diameter, inches	09⅝
Inside diameter, inches	05¾
Effective thrust surface, ahead, square inches	289
Thrust collars on shaft, cruising:	
Number of	7
Thickness, inch	00½
Space between, inch	00⅝
Outside diameter, inches	08⅝
Inside diameter, inches	05¾
Effective thrust surface, ahead, square inches	105.5
Line shaft bearings, wing, number of, each side	2
length, inches	11¾
center, number of	5
length, inches	11¾
Stern-tube bearings, forward, length, inches	21
after, length, inches	33
Strut bearings, length, inches	33

Propellers.

The propellers are of the three-bladed, true-screw type, and are solid manganese-bronze castings with the faces of the blades machined.


U.S.S. Patterson
TRIAL Standardization
COURSE Delaware Breakwater
DATE August, 9 1911.
DATA.
SCREW PROPELLERS
REVOLUTIONS PER MINUTE.
SPEED IN KNOTS PER HOUR.
INDICATED, SHAFT AND EFFECTIVE HORSEPOWER.
PROPULSIVE COEFFICIENT

Propeller Data.

Number of blades, each	3
Diameter, feet and inches	5–03
Pitch, feet and inches	4–10.1
Projected area, square feet	12.83
Helicoidal area, square feet	14.59
Disc area, square feet	21.65
Ratio, pitch to diameter	0.922 :1
projected area to disc area	0.593 :1
Thickness of blade at root, inches	02 1/16
Height of lower tip of blade above keel, wing, inches	01½
Depth of lower tip of blade below keel, center, inches	16½
Immersion of upper tip of blade at 8 ft. 4 ins., draught:	
Wing, inches	35½
Center, inches	53½

Condensers.

There are two main condensers of the usual destroyer type with straight tubes expanded into the tube sheet at one end and packed at the other end with cotton-tape packing and screwed ferrules. There is one cylindrical auxiliary condenser mounted on a horizontal combined air and circulating pump.

Condenser Data.

	Main.	Auxiliary.
Number of tubes, each	2,024	336
Outside diameter of tubes, inch	005/8	005/8
Thickness of tubes, B. W. G., number	18	18
Length between tube sheets, feet and inches	14–6	4–7⅞
Cooling surface, each, square feet	4,801	256

Feed-Water Heater.

Number	1
Type	Cylindrical, surface
Number of tubes	436
Outside diameter of tubes, inch	005/8
Thickness of tubes, B.W.G., number	18
Length between tube sheets, feet and inches	7–0
Heating surface, square feet	499.38

Oil Cooler.

Number	1
Type	Four-pass, cylindrical, surface
Number of tubes	200
Outside diameter of tubes, inch	005/8
Thickness of tubes, B.W.G., number	18
Length between tube sheets, feet and inches	5–04¼
Cooling surface, square feet	175.22

REVOLUTIONS PER MINUTE.

Data of Pumps and Auxiliary Engines.

Name.	Number.	Type, make and location.	Diameter of steam cylinder, inches.	Diameter of pump cylinder, inches.	Stroke, inches.
Pumps:					
Main air	2	Twin, vertical beam, Blake, engine room	12	26	18
Main circulating	2	Engine-driven centrifugal, Cramp, engine room	7	...	6
Main feed	2	Vertical simplex, Blake, engine room	14½	10	12
Auxiliary feed	2	Vertical simplex, Blake, one in each fireroom	14½	10	12
Engine-room fire and bilge	1	Vertical simplex, Blake, engine room	10	7	8
Fireroom fire and bilge	2	Vertical, simplex, Blake, one in each fireroom	8	5	12
Forward bilge	1	Vertical simplex, Blake, forward side B. H. No. 28, berth deck.	3½	4	4
Auxiliary condenser	1	Horizontal simplex, combined air and circulating, Blake, engine room.	6	8 & 8	7
Lubricating oil	2	Vertical simplex, Blake, engine room	4½	5	6
Oil-cooler circulating	1	Vertical simplex, Blake, engine room	6	7	8
Fuel-oil service	4	Vertical duplex, Blake, two in each fireroom	4½	3	4
Fuel-oil supply	2	Vertical simplex, Blake, one in each fireroom	6	7	12
Evaporator feed	1	Vertical simplex, Blake, engine room	3½	4	4
Distiller fresh water	1	Vertical simplex, Blake, engine room	3½	4	4
Windlass engine	1	Vertical double-cylinder, Williamson, forward side of B. H. No. 12, main deck.	4	...	6
Steering engine	1	Vertical double-cylinder, Williamson, pilot house	5	...	5
Air compressor	1	4-stage, steam-driven, capacity 20 cubic feet per hour at 2,500 pounds per square inch.			
Electric generator	2	5 kw., G. E. Co., driven by horizontal Curtis steam turbines, engine room.			
Forced-draft blower	4	Sturtevant, driven by vertical Terry steam turbines, two in each fireroom.			

Boilers.

There are four White-Forster oil-burning water-tube boilers arranged in two firerooms, with three smoke pipes. The boilers, oil-burning apparatus, fireroom auxiliaries, etc., are the same, with the exception of a few minor details, as those of the *Warrington* and *Mayrant,* described elsewhere in this number, so that only the principal data will be repeated.

Boiler Data.

Heating surface, each, square feet	4,500
total, square feet	18,000
Combustion space, each, cubic feet	394.74
total, cubic feet	1,578.96
Ratio, combustion space to heating surface	1 : 11.4
Designed working pressure, pounds per square inch	250
Area of smoke pipe, forward, square feet	13.32
middle, square feet	26.63
after, square feet	13.32
Ratio, combustion space to smoke-pipe area	29.65 : 1
Height of smoke pipes above oil burners, mean, feet	33.17

Torsion Meters, Measuring Tanks, Etc.

The torsion meters used on this vessel were of the improved Metten type, and the apparatus for measuring fuel-oil and feed-water consumption was the same as that used on the *Mayrant,* described elsewhere in this number.

TRIALS.

The standardization trials were run over the measured-mile course off Delaware Breakwater on August 9, 1911. The various four-hour trials were run off the Delaware Capes and in the lower part of Delaware Bay on August 10 and 11, and September 7 and 8.

Data for Four-Hour Runs.

Date and time of trial	Sept. 8, 1911. P. M.	Sept. 7, 1911. P. M.	Sept. 8, 1911. A. M.	Aug. 11, 1911. P. M.	Aug. 10, 1911. P. M.	Aug. 11, 1911. A. M.
Mean draught on trial, feet and inches	8-04 17/32	8-05 3/16	8-05	8-03 1/4	8-04 3/8	05 1/8
Corresponding displacement, tons	742.1	750.3	748.0	736.7	746.7	756.8
Trim by stern, inches	02 5/16	00 3/8	01 1/2	09 1/4	07 1/8	05 1/8
Speed of ship, knots	12.108	16.084	20.036	25.098	27.571	29.685
Revolutions per minute of main shafts :						
Starboard	298.124	405.910	506.830	670.322	707.503	810.932
Center	237.857	331.750	415.170	579.859	678.364	750.771
Port	295.680	397.560	485.420	601.713	704.247	785.272
Mean	277.220	378.410	469.140	617.298	696.704	782.325
Slip of propellers in per cent. of their speed :						
Starboard	15.00	17.08	17.27	21.64	18.44	23.40
Center	—6.53	—1.46	—0.10	9.41	14.94	17.26
Port	14.30	15.33	13.62	12.70	18.07	20.90
Mean	7.59	10.80	10.26	14.58	17.15	20.52
Pressures :						
Boilers, gage, pounds	244.0	251.0	250.0	248.0	gage out	244.0
Main steam, engine room, gage, pounds	235.6	248.0	247.0	gage out	238.0	239.0
Auxiliary steam, engine room, gage, pounds	gage out	gage out	gage out	244.0	235.0	236.0
Auxiliary exhaust, engine room, gage, pounds	...	5.1	5.5	15.0	...	13.4
Main H.P. steam belt, absolute, pounds	15.0	32.6	49 3	110.0	166.0	215.0
H.P. cruising steam belt, absolute, pounds	77.3	180.6	232.0	...	...	...
I.P. cruising steam belt, absolute, pounds	25.3	71.4	117.0	245 0	...	...
L.P. starboard steam belt, absolute, pounds	5.0	12.2	18.0	26.0	36 6	46.5
L.P. port steam belt, absolute, pounds	5.0	12.3	18.0	25.4	37.4	46.1
On turbine glands, gage, pounds	2.1	2.2	8.6	3.8	4.8	5.2
In lubricating system, gage, pounds	4.0	3.7	4.2	9.3	7.6	9.1
Vacuum in condensers :						
Starboard, inches of mercury	29.5	29.0	29.5	29.0	28.6	28.10
Port, inches of mercury	29.2	29.0	29.4	29.0	28.8	28.40
Mean, inches of mercury	29.35	29.0	29.45	29.0	28.7	28.25
Air pressure in firerooms, inches of water	2.13	2.18	2.69	3.30	3.95	4.80
Fuel oil to burners, pounds	213.0	206.0	201.0	207.5	212.0	217.5

Temperatures, Fahrenheit:						
Injection, degrees	74	74	73	78	78	77
Discharge, degrees	77	80	78	92	98	101
Feed to heater, degrees	81	87	82	103	105	111
Feed from heater, degrees	193	192	187	209	177	187
Lubricating oil to cooler, degrees	92	95	98	116	117	120
Lubricating oil from cooler, degrees	86	88	90	102	102	103
Fuel oil to boilers, degrees	156	172	164	160	160	158
Engine-room working level, degrees	116	...	103	98	103	97
Fireroom working level, degrees	114	119	111	115	117	111
Outside air, degrees	74	76	74	79	81	80
Smokepipe gases, degrees	364	325	412	392	475	558
Auxiliaries:						
Revolutions or double strokes:						
Main air pumps, starboard	24.3	24.3	16.3	27.8	29.8	32.4
port	not running	not running	16.2	27.2	23.0	30.8
Main circulating pumps, starboard	199.2	236.0	322.0	336.0	349.0	353.0
port	200.8	228.0	326.0	330.0	342.0	342.0
Main feed pumps, forward	not running	17.8	19.8	29.0	32.1	28.4
aft	8.8	not running	not running	not running	24.0	26 3
Forced-lubrication pumps	51.2	61.0	64.0	86.0	97.0	108.0
Fire and bilge pumps, engine room	...	...	...	...	...	52.3
fireroom	59.6	57.0	49.0	73.0	73.0	74.3
Fuel-oil pumps, forward fireroom	not running	not running	not running	36.6	37.0	46.0
after fireroom	14.5	21.3	33.8	22.2	41.3	44.0
Forced-draft blowers, forward fireroom	not running	not running	not running	1,073.0	1,113.0	1,164.0
after fireroom	1,233.0	1,235.0	1,157.0	1,354.0	1,384.5	1,377.5
Dynamo, ampères	30.3	23.7	31.0	32.5	35.8	35.6
Number of boilers in use	1	2	2	4	4	4
Average number of burners in use, each boiler	3.5	2.6	3.5	4.1	6.4	7.5
Horsepower, main shafting:						
Starboard	234	645	1,232	3,189	3,049	4,271
Center	84	296	565	1,866	3,189	4,323
Port	244	623	1,051	1,896	3,095	4,028
Total	562	1,564	2,848	6,951	9,333	12,622
Deduced data:						
Square feet of heating surface per S.H.P.	8.007	5.754	3.160	2.590	1.929	1.426
Sq. ft. cool. surf. (main condensers) per S.H.P.	17.085	6.139	3.371	1.381	1.029	0.761

THE NAVY'S COAST SIGNAL SERVICE.

By Lieutenant Commander D. W. Todd, U. S. Navy.*

During the Spanish-American war the Navy Department had a complete coast signal service organized by the Chief Intelligence Officer, Captain John R. Bartlett, U. S. Navy. It was manned and officered by volunteers. The stations were established at life-saving stations, at light-houses, and at other points along the coast where necessary, and all were connected by telegraph to the Department. Means were provided for signaling by international code and by wigwag by day and by means of lights at night. All signals were visual.

In July, 1898, Mr. Marconi's wireless apparatus accomplished the great feat of reporting the yacht races at the Kingston regatta, a large number of correct messages being exchanged between a press boat and the shore at distances extending up to twenty miles.

Wireless telegraphy had no part in the war, and the results obtained by Mr. Marconi in 1898, which were considered remarkable at that time, compared to what is now being accomplished, show the very remarkable developments which this science has undergone in thirteen years.

It is believed that the day is not far distant when visual signals between ships and between ship and shore will be relegated to the past, and all communications will be by wireless telegraphy or telephony. When that time comes, signals will be independent of wind, fog and other weather conditions, and of time, whether night or day, within certain limits. At present the coast signal service of the Navy consists of wireless telegraph stations alone.

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* Read before the American Institute of Electrical Engineers, November 14th, 1911.

The necessity for a complete coastwise wireless system in time of war, for the control of the fleet, for obtaining information of movements of the enemy, and for the purposes of assisting in local defense can not be questioned.

THREE CLASSES OF STATIONS NEEDED.

High-power stations are needed for communicating with ships at sea, especially with ships fitted for long-range work, and stationed to act as repeating ships for battleships, destroyers and other ships whose masts do not permit them to have a great range. They are needed also to replace cable communication between important points, having practically no land intervening, such as between the United States and the Canal Zone and with the islands of the Pacific, or, specifically, between California and the naval station at Pearl Harbor, between the latter and Tutuila, Samoa, and Guam, and between Guam and the Island of Luzon, Philippines. These should all be within defenses, for their importance to all naval operations invites attack.

The first station of this type is being built on a site obtained from the War Department at Fort Myer, Va. It has been named the Arlington station, and is designed for—

(1) Experimental work in connection with apparatus and equipment for other high-power stations to be built.

(2) Long-range communication with ships at sea.

(3) Direct communication with the important navy yards on the Atlantic coast, with Porto Rico, Guantanamo and Colon. How much of this can be done by day and how much will have to be held for night work are interesting points to be determined.

(4) Forwarding important official dispatches of the War Department to their inland stations, if practicable.

(5) Forwarding important official dispatches to distant points for other Departments of the Government, if practicable.

(6) Dissemination, at stated hours, of information needed by the mariner—time signals, obstructions to navigation, such as wrecks, derelicts, ice, etc., and weather reports.

After some years another such station will be necessary for the Atlantic coast to supplement the work of this one in controlling the fleet in the North Atlantic. The Pacific coast will also have two high-power stations probably.

Medium power stations are needed at certain important points not liable to attack, to keep in touch with one another and with the main fleet or its dependencies operating in their vicinities; to insure direct communication between points where land-wire or cable communications are liable to interruptions and when certain distances are required to be covered by wireless under disadvantageous circumstances, *i.e.*, over land, especially mountainous country.

There are but two such stations now, Key West and Colon, and the following are contemplated: New York and Charleston Navy Yards; Porto Rico; Unalga Island, in the Aleutian chain; Cordova, at the north end of the War Department's Washington-Alaskan military cable; North Head, Wash., to work with Cordova in case of breakdown of this cable; and one on the Gulf of Mexico.

Coast stations proper, each capable of communicating with its neighbors on either side, will, in time of war, be the eyes and ears of the coast, supplementing land-wire communications, gathering information from seaward, and keeping in touch with vessels whose wireless range is limited, such as coast-defense and patrol ships, improvised fleet auxiliaries and merchant ships.

There are at present forty-two such stations, most of them having been established five or six years ago.

Since a coast wireless system is a necessity for war, and assuming that the abolition of war is still several generations in the future, it must be prepared for its part in time of peace, the same as any and every other feature of the naval service. This paper is intended to deal principally with this subject.

NEED OF LEGISLATION REGULATING WIRELESS COMMUNICATION.

The most important stumbling block in the way of getting the best efficiency out of the Navy's wireless system is the commercial shore station. Amateurs often show up in print, and they are sometimes troublesome when near a naval station, but few of them send with much power. If they would confine themselves to receiving, they would be welcome to intercept all the messages they could spare the time for (with reservations), and their sending over three or four city blocks would be inoffensive ordinarily. When they invest in one and two-kilowatt sending sets, they are a nuisance, and need regulating as much as commercial concerns. Then they indulge in the practical jokes we read about. Fortunately, they are not at the key much of the time, and they usually use short wave lengths.

If the Navy could be given the shore end of all commercial coastwise wireless communication with ships, the writer believes that the maximum good would result. A number of wireless concerns have gotten into difficulties, financial and legal, and the rest now seem to be intent on putting each other out of business by suits concerning patents, so we have hopes. A chain of stations under one system of control would result in a minimum of interference and a maximum of satisfactory legitimate wireless work. By "legitimate work" is meant wireless communication with ships at sea, the true field for wireless telegraphy. For military purposes and for certain over-sea work, wireless communication between shore stations is feasible and necessary, but all relaying of messages between points satisfactorily connected by land wire should be reduced to a minimum. In time, this point will be covered by legislation. In the past, any wireless concern which has proposed to operate over land in competition with land lines has been either extremely optimistic or has not been acting in good faith. Tomorrow, the problem of non-interference may be solved, but it is believed that other problems will arise which will prevent any such scheme from becoming a commercial success.

PRESENT STATUS OF COMMERCIAL WIRELESS WORK.

There is no law, no order; and with an increase of the number of commercial shore stations conditions will be chaotic. Any wireless company, any individual, can put up a station anywhere, of whatever power or range it or he may please. Any wave length may be used, any kind of transmitter. There is no restriction as to hours of working. The time signals sent out by naval stations, the information concerning wrecks, derelicts, ice, aids to navigation displaced, storm warnings, all are subject to interruption by neighboring stations, and the mariner may listen for them in vain. Vessels in distress may not be able to make known the fact or extent of their plight or their positions, on account of press dispatches being relayed along the coast, or a long invoice of goods being repeated by wireless for advertising purposes, between cities separated by a twenty-five-cent telegraph rate. The government station, most useful to shipping of all kinds, may be seriously handicapped by malicious interference. Not only are land stations troublesome to each other, but ship stations are poorly managed. Ships in harbor use their sets for needless work with a station sometimes less than a mile away. They send in position reports too frequently. The operators engage in personal chatter.

Attention has often been called to these points, but since, apparently, we are no nearer legal relief, it is the duty of all who believe in organization and regulation for increasing the efficiency of any useful development of time to keep up the cry.

WHAT KIND OF REGULATION DO WE NEED?

Should war break out, the military necessity for suppression of most commercial and private shore stations and government control of a few would be so obvious that the Secretary of the Navy would get the necessary legislation for the asking. But we need some legislation now, such as a law licensing all

stations by the Department of Commerce and Labor and under regulations to be framed by it. The latter might regulate:

(1) The hours of operation of a station.

(2) The power to be used, depending on the business for which the station is licensed.

(3) The wave lengths to be used.

(4) The type and degree of efficiency of the apparatus.

(5) Ships might be prevented from using their sets within certain limits when making or leaving port, except in emergencies, and shore stations prohibited from relaying between points covered by land wires.

(6) All coastwise stations should be opened to international traffic under the rules of the International Wireless Convention.

THE INTERNATIONAL UNION.

In regard to the last suggestion let us say a few words. The nations send representatives to Berlin to further a scheme for international wireless communication between ship and shore, so that any person on a ship carrying wireless apparatus may send a message through a coast station of any country, and prepay the charges on board, and so that proper arrangements may be made for satisfactory communication between vessels and for succoring vessels in distress. This country is represented, and well represented. We are given ample opportunity to express our views. Result—nothing, as far as we are concerned. Commercial companies prevent the ratification of the Convention by the Senate, and we are outcasts in the wireless brotherhood of nations. If a foreign ship or station accepts a message from an American ship, it is through courtesy only. One of the greatest nations of the world, with thousands of miles of sea coast, with outlying island possessions, one whose stations will always be a factor in facilitating and guarding the safety of the world's commerce, it without standing. Foreign vessels on our coast get no response to their calls, or are told that a certain station takes messages from certain ships only, or, in the case of a naval

station, that any message will be forwarded "Collect" only. This can not go on. Another International Convention is at hand. We shall probably be represented, but the arguments of rival commercial companies will probably prevail, since the Government as a whole has not yet realized the importance, the tremendous possibilities, and the astonishing growth of this new art which Science has developed and man is bending more and more to his purposes daily.

PRIVATE OWNERSHIP OF TELEGRAPH LINES.

One argument is often heard. In foreign countries generally, the Government owns all coast wireless stations and all the land telegraph lines as well, so that the international regulations are easily applied. They can be made to apply here. Wireless tolls on board ship and at shore stations, naval and commercial, can be fixed. The land telegraph companies and the cable companies can keep all wireless stations informed of their tariffs, and the distribution of monies collected for messages sent partly by wire or cable, and partly by wireless, can be made the duty of a special officer of the Department of Commerce and Labor at each large seaport, or for a certain district. With such arrangement charges would be made for the commercial work of naval stations, and one or more accounting officers would attend to their collection.

UNDER PRESENT ADVERSE CONDITIONS WHAT IS BEING DONE?

Having unsatisfactory conditions to work under, it is the duty of the Navy's system to accomplish its work in spite of these conditions.

Its principal work is to keep itself in efficient condition, keeping pace with the development of the science and improvements in apparatus, so as to be prepared for a sudden war.

It has other duties in times of peace, but we may call them

routine duties. When high-powered stations are in operation they will have special duties assigned, but all will tend toward developing the capabilities of all stations to the utmost for war.

To keep them in efficient condition the stations must have work. The personnel must be kept employed, the weak points of apparatus must be discovered and strengthened, and the work must be so allotted that each station does the most it is capable of without crowding its neighbors. Keeping in touch with the ships of the Navy does not mean enough work at present. As the range of all stations is being steadily increased they may become fewer in number, as far as the Navy is concerned.

BENEFITS TO SHIPPING.

Since the Navy must have its system for its own purposes, the system is made as useful as possible in times of peace. Hence, news of the ocean, concerning derelicts, wrecks, ice, disturbed conditions of the weather are gathered from passing vessels and transmitted to the Hydrographic Office or the Weather Bureau, whichever may be concerned. News of menaces to navigation are received by wire by coast stations and sent broadcast four times daily; also storm warnings. Between 11:55 and noon, Washington time, on this coast and that of the 120th meridian on the Pacific coast, wireless time signals are sent out for the use of navigators. In ordinary circumstances these are followed by a weather forecast, received from the Weather Bureau by wire. It is proposed to send time signals at night also, and it is expected that the necessary arrangements can be made—probably first for the new station at Arlington. Ships can get hydrographic information and weather reports at any time on request. At all stations, with few exceptions, a constant watch is kept, and distress calls are far more likely to be picked up by a naval wireless station than by a commercial station or merchant ship, since the latter have, in most cases, one operator only.

COMMERCIAL WORK.

In addition, commercial messages are handled whenever it can be done without direct competition with commercial companies, no charge being made for the wireless service. In return for this free wireless service the stations are relieved from the handling of money and accounts. As a message is received from a ship at sea it is put on a land wire and sent "collect" to address.

The total amount of paid business of the telegraph companies being increased, they accept all messages and stand the losses if "collect" messages are refused. A "paid" land-wire telegram received at a station is transmitted to a ship at sea as soon as the ship comes within range. In time the Secretary of the Navy will be authorized to make a charge for the wireless service, and then the Government will assume some responsibility for the accurate receipt and the delivery of the message to a land wire or to a ship.

RELAYING.

Naval coast stations could be given enough work by relaying official business along the coast to the various navy yards and naval stations, and we believe that the ultimate result would be that commercial shore stations would have to go out of business. That is not the policy of the Navy Department at present. "Live and let live," and "Wireless for communication with ships or over sea," generally, are the mottoes. Our stations are required to do all in their power to set a good example of non-interference. Only such "test" messages as are necessary to keep operators vigilant and to keep the officers responsible properly informed of the operative condition of their stations and the reliability of communication are relayed. Relaying of important or urgent messages whenever necessary is provided for, the intent being that no regulation or special instructions shall stand in the way of getting aid to any vessel in distress at the earliest practicable moment; to delay the widest dissemination of information in regard to

dangerous menaces to navigation, or of storm warnings; or important official messages in emergencies, such as when land wires are down; or even very urgent commercial messages, when properly authorized.

INTERFERENCE.

Now comes a much-discussed subject. Having uncontrolled and sometimes unruly neighbors to get along with, and since, generally speaking, wireless interference is mutual, what arrangements can be made to increase the total amount of wireless work done by all parties? A division of time between government stations and commercial stations will do away with some interference. This works well on the Pacific coast, and might be put in practice everywhere if we had only one commercial company to deal with. If two of our own shore stations cannot work without interfering with each other without a division of time, the indication is that one should handle all the work and the other be abolished. As intimated once before, abolishment of all commercial shore stations would solve many problems of interference. In certain places a division of time works well. Key West, for instance, works on schedules very satisfactorily. Its interference comes mostly from Cuba, but it also has to use schedules to keep its ship and shore-station work separated. These schedules change with the season of the year and the amount of work done with certain stations, but the result is a nearly continuous flow of work. This station will have two transmitting sets in the near future—a medium-power set for communication with Washington, San Juan, Guantanamo and the Canal Zone, and a low-power set for messages to and from passing ships. This will necessitate a division of time between the two sending sets. It is probable that the new Arlington station will work on schedule, in order that it may interrupt the local work of a certain station at the same hour every day, which hour can be published to all ships. This will prevent the ships from uselessly interfering with other com-

munications in their neighborhoods by long calls for a station which is not listening for ships. The same or another schedule will probably be used for ships of the Navy, to relieve them of the necessity, in ordinary times of peace, of listening with the receiver set for a very long wave length. This brings us to the subject of

WAVE LENGTHS.

The use of different wave lengths to avoid interference is a complex and baffling subject.

For the principal ideas brought out in the following discussion the writer is indebted to a carefully-prepared paper written by Commander S. S. Robison, U. S. Navy, whose work in developing the wireless system of the Navy is well known. Given an ordinarily good sending set and the same kind of a receiver, the first in good adjustment for sending out a pure wave, that is, a wave with one crest, and the latter in the hands of an operator who understands how to adjust it, a change of three per cent. from the wave length for which the receiver is set when in tune with the sending wave will cut down the strength of signals to one-half. A change of ten per cent. will cut them out entirely when the distance is short. This means that if all apparatus were efficient a number of sets of communications could take place simultaneously in a given locality, provided that the sending stations used wave lengths sufficiently far apart and the stations were not too near each other. If this were all the story it might appear that suitable assignment of wave lengths could be made to cover all needs.

DEFECTS OF TRANSMITTERS IN ORDINARY USE AT PRESENT.

In the first place, most commercial transmitting sets have the aerial or radiating circuit so coupled to the condenser or closed circuit that a pure wave is not sent out. The energy is radiated in two waves, one shorter and one longer than that for which each circuit is adjusted, due to the inductive reaction between them, or the wave transmitted has two crests.

The longer wave usually has the more energy, that is, has the higher crest. An operator can receive a message by setting his receiver to either wave, if he is near enough. He usually chooses the one with the most energy, the one which sounds loudest in his phones. The energy in the other is wasted, but it interferes, it troubles some other station. Naval ships and shore stations are setting a good example in this regard, as all transmitters are being adjusted for sending out one wave only, and the damping is being reduced so that that wave is sharp, which means that all receivers not set very closely for the sending waves will hear nothing. Commercial wireless concerns almost invariably operate stations on board ships in conjunction with shore stations established especially for keeping in touch with them. Those which operate the largest number of ship stations prefer to have their transmitters send on a broad-crested wave. Why? Because careful adjustment, and hence trained operators, are not necessary, and so that calls will not easily be missed. Receivers do not have to be set accurately, they need not be very elaborate, and no great watchfulness on the part of the operators is necessary. A maximum of interference would result if it were not for the fact that the wave lengths of ships vary sufficiently to permit tuning out some of them.

In order that ships may surely hear each other's distress calls, and exchange weather reports and other news of the sea, it is desirable that they all use the same wave length or "tune" for both sending and receiving. This would result in a great deal of interference and be prohibitive in the neighborhood of great seaports. The same would apply to shore stations if they could use the same tune. Here comes the relief from too much business being transacted on one tune; also a difficulty. On account of distances between masts of ships and their height an ordinary ship's set can not use waves over 600 meters long efficiently. Until recently, the Navy had 425 meters as a standard, because that was the best average length for the wireless set formerly provided. The standard is now 600 meters, to get away from merchant ships,

—300 to 400 meters is the average used by them. Shore stations are naturally designed to have a greater range than ships have, as they are usually intended to communicate with each other at greater distances as well as with ships, must send over land or partly over land, and these considerations point to waves over 600 meters in length as being most efficient for their use. In fact, shore stations of all kinds have generally used any tune for which the transmitter could conveniently be adjusted for efficient working, say from 600 to 1,500 meters. Each has its own sending tune, without reference to its neighbors, and ships have to know it approximately in order to receive the signals.

CALLING TUNES.

With these individualities calls may be missed unless all operators keep shifting the settings of their receivers over the range of tunes used by ships and shore stations; however, two ships or stations communicating do not interfere with two other ships or stations as much as if all ship transmitters were set to one tune and all shore transmitters to another. As the amount of wireless business is increasing rapidly, and all ships use about the same tunes, it will become more and more apparent that the question of wave lengths will have to be settled eventually by regulations, changing from time to time as conditions change.

USE OF DIFFERENT TUNES FOR SENDING AND RECEIVING.

Suppose ships and shore stations have one tune for sending and one for receiving. Since the sending tunes are different for ships and coast stations, any receiver set for one will not hear calls from the other. To hear both ship calls and shore calls, the receiver must be adjusted first for one and then the other, or two receivers must be used, to be connected in the aerial circuit alternately, or simultaneously.

CHANGE OF WAVE LENGTHS.

What are needed, in addition to standard calling tunes for ships and shore stations respectively, are transmitters with small damping in the aerials which can call on one tune and then be shifted to another at least 100 meters longer or shorter, or better, to any one of three or four tunes. Receivers must be selective, and both receivers and transmitters capable of accurate adjustment for the tunes used. Then one ship calling another uses the standard ship's calling tune. The ship called acknowledges by same tune and, since only the receiver can be interfered with, the latter designates the tune, one which is not being used in her range. The designation of tunes should be made standard and simple, as " Tune B," " Tune C." Both ships now shift transmitters and receivers to the new tune, and the correspondence is finished without further change. Immediately after the last acknowledgment is made both ships shift back to the calling tune. The same method can be used for communication between two shore stations. Between a ship and a shore station the scheme does not work quite so simply. The ship calls the station; the latter designates the sending tune to be used by the ship, but the station cannot use the same; either the station uses its own calling tune thereafter or must designate one which will not interfere with another shore station receiving a call from a third. This suggests further complications, because a ship or station does not hear all the interference that the other is experiencing. To start again, a ship calls a shore station to send a message. Shore station answers; indicates that it has a message for the ship, and suggests Tune C, say, for the ship to use, and indicates that it wishes to shift to Tune K. Ship finds Tune C in use within hearing, and does not wish to interrupt a message being received; also finds that another shore station is using Tune K, which would prevent her receiving; she suggests Tune B for herself and Tune M for the station, indicating interference on C and K. This may be satisfactory to the shore station and it may not, and so on. Possibly each station on being called will some day have to indicate all tunes in

use in her hearing, also her preferred tune, and the calling station may take it or choose another. This is carrying the possibilities rather far, and refers to some future time, when more ships will plow the sea, when all ships of every class will consider a wireless installation as necessary as a compass, and the ranges of wireless communication will be vastly multiplied. It also indicates a problem to be solved, and no one who has read the history of the development of this art will have any doubt of its solution within a few years.

STANDARD CALLING TUNES.

The Navy has made a start in the matter of standard calling tunes, and, desiring to set a good example to merchant shipping for the general welfare, has published the changes being made in the hopes that others may make the same changes; that more efficient arrangements may be made by some one or more commercial concerns; or that, at least, discussion may be started. Information concerning the Coast Signal Service and about man-of-war methods of handling wireless messages and installations is given to the shipping world through the medium of the Hydrographic Office of the Navy Department. The latest changes were printed on the back of the Pilot Charts for the North Atlantic and Indian Oceans for October, and that for the Pacific Ocean for December. The following information is given:

(a) Advantages offered to merchant marine by coast stations.

(b) Information furnished to shipping.

(c) Description of time signal and method of receiving same.

(d) What stations are open to public business and under what conditions.

(e) Code used.

(f) Changes being made in sending wave lengths.

(g) Method of communicating with naval stations for best results.

(h) How to make complaints, if necessary.

(i) Detailed information concerning present status of stations. These need revision already, on account of constant changes.

With the exception of Colon and Key West, the transmitters of all stations are being altered to call on a 1,000-meter wave with one sharp crest, either by installation of high-frequency quenched-spark-gap sets, or by changing oscillation transformers from direct to inductive coupling. Where new transmitters are provided quick changes of sending tunes are provided for. Where low-frequency sets are installed several sending tunes will be made available, but the first step being taken is to adjust to the standard calling wave. All ships' transmitters are being adjusted for the new standard ship-calling tune, which we designate Tune F. The shore stations have three classes of communication: (1) With each other; (2) with naval vessels, and (3) with merchant vessels. They use the same sending tune at present, let us say, for all three classes, but must be prepared to receive calls on Tune J, that of other coast stations, Tune F, men-of-war, and a number of tunes from A to F used by merchant vessels. The receiver may be made to cover a number of waves of the kind emitted by merchant ships, but no one receiver will pick up calls from all of them, from sets sharply tuned on 600 meters and others sharply tuned on 1,000 meters, unless the operator constantly changes the variable inductances, condensers and coupling over the desired range of tunes.

USE OF TWO RECEIVERS.

To show proper respect for human nature in the form of the average operator, it was considered necessary to relieve him of some of this constant or frequent change by giving him two independent receivers, a listening key and a special telephone head set. One receiver is termed the long-wave receiver, and is set for Tune J. The other is the short-wave receiver, and the operator is supposed to tune it so broadly

that it will pick up all calls on the shorter waves used by merchant ships, and to occasionally set it for the calling tune of men-of-war, or vice versa. Through the listening key one receiver is connected by a special cord to the telephone over one ear, and the other receiver to the other ear in the same manner. Hearing a call, the listening key is thrown toward one receiver which connects both ear telephones to that one and cuts out the other. Should no call be heard, the key is thrown the other way, the other receiver tuned sharply for the call, and the call acknowledged.

DEFECTS OF THE TWO-RECEIVER ARRANGEMENT.

It will be noted that the operator cannot miss a call from another coast station, but he cannot hear all ship calls on one receiver automatically. A certain amount of manipulation of the short-wave receiver is necessary in order that no calls may be missed, especially distress calls which may be on any wave, at present. When there is a constant flow of work, not many calls will be missed, but when work is slack, smoking and reading will interfere. Again, many men hear better with one ear than with the other, and an operator may hear one set of calls and not the other. Furthermore, medium-power stations—Colon and Key West at present, Unalga, Cordova and North Head next summer—need to use waves longer than 1,000 meters to cover great distances over sea by daylight, or moderate distances over intervening land, and the nearest coast stations must be ready to hear them and be heard; while the high-power stations will use waves of 3,000 meters and above. As these latter are expected to handle government work exclusively, they will probably work on schedule, and each secondary or tertiary station will have certain hours when it will listen for calls on these very long waves on a special receiver. To go back to our medium-power station calls, coast-station and ship calls, it is plain that two receivers are not sufficient. Now comes the

TUNE SHIFTER.

This is simply a clockwork mechanism which switches the operator's telephone from one receiver to another every fifteen or twenty seconds. Having such an instrument and, say, three receivers, any station is prepared to hear any one of these sharp tunes once per minute, and a considerable range of calls from broadly-tuned ship sets, if they are not too distant. An operator coming on watch may then see all receivers in adjustment, put his phones on his head, adjust the detector common to all receivers, see that his shifter is wound, fill his pipe, reach for a book, put his feet on the table, and let the tune-shifter do the rest. This is about to be tried out.

THE CALL RECEIVER.

Furnishing each of forty-five stations with three receivers, each receiver costing from $275 to $375, will not be practicable. Important stations may have three, others two, others one. Among other things which we need is a special call receiver. This combines three receivers in one, and may be used for picking up calls only. Every fifteen or twenty seconds a clock-work mechanism shifts the adjustments of a single receiver, so that it automatically jumps from 400 to 600 to 1,000 to 2,000 meters. Hearing a call, the operator notes what tune it is on, stops the mechanism, or cuts in a more effective receiver, and adjusts it for the tune. This instrument is not invented yet.

ULTIMATE VALUE OF SPECIAL DEVICES SUGGESTED.

These devices will only partially succeed. Our greatest hope is in getting as far away from commercial tunes as possible, and putting certain tunes into such constant and general use that others will keep away from them for their own protection. In time, even if not regulated, commercial concerns must agree among themselves on some scheme to prevent interference. The Navy can only set a good example and

urge them to change their system of working or their apparatus. Our relations with them are amicable, but they are severe critics, and not strong on seeing the beams in their own eyes. We welcome criticism, and all complaints are investigated and suitable action is taken wherever necessary or desirable.

NUMBER AND DISTRIBUTION OF STATIONS.

Forty-four stations are in operation. Both coasts of the United are covered, there are two in the West Indies, one in the Canal Zone, five in Alaska, one at Honolulu, one at Guam, and one at Cavite. Another will soon be in operation at the Naval Station, Olongapo, Philippine Islands. Three Atlantic-coast stations are on light-vessels, on Nantucket Shoals, Diamond Shoals, and Frying Pan Shoals off Cape Fear. These are advanced points to seaward for the Newport, Beaufort, N. C., and Charleston, S. C., stations, respectively, and are intended to benefit shipping in every possible way.

STATIONS PROJECTED.

Six high-power stations, and a medium-power station on Porto Rico are first on the program for erection as soon as funds permit. During the coming summer a new medium-power station, for which funds are available, is to be established on Unalga Island near Unalaska and near the entrance to Bering Sea, to connect up all Alaskan stations for day work, and for the benefit of all vessels crossing the North Pacific or entering Bering Sea. It will be expected to communicate with stations in the State of Washington by day in favorable circumstances, regularly at night, and to talk with Honolulu and Japanese stations occasionally at night.

VAGARIES OF WIRELESS COMMUNICATION.

Wireless communication over the Pacific is far more satisfactory than on this side of the continent. No one knows why. In this connection it is pretty well known that winter

is better than summer for wireless work, and that daylight communication suffers from an absorption of the energy which is generally less at night, and sometimes absent.

This increase of range at night is not reliable, as the absorption at night is sometimes as great as by day; then the ether will clear in some unexplained manner and astonishing feats will be reported,—mountain ranges that ordinarily blanket a station count for nothing, and a weak station at Honolulu is read with ease by a number of Pacific-coast stations. Now is the high tide of the year for wireless work. All of the Alaskan stations reach each other. The masts at Unalaska blow down; the electrician in charge rigs up an aerial on the stumps, and does the same work as before, due to the favorable season. Pacific liners far across the Pacific, and the Japanese stations, are heard in Alaska and on the west coast. With a 40-foot portable mast of the Signal Corps of the Army, long messages from a ship of the Navy carrying the President to Colon were read at Fort Leavenworth. This was last year The other day the captain of the *Cincinnati* wished to know about a wave meter intended for his vessel. Mare Island, having new 300-foot masts, sends the message to Washington via Key West, Fire Island and Philadelphia. The officers of the Mare Island Navy Yard, wishing to congratulate their late commandant on having a hundred ships under his command in the North River, they send the message by wireless via Colon, Key West and Atlantic coast stations. On another night Colon communicates direct with Newport. These are called " freak" messages. If all the above long-distance work were day-work, we would be several years ahead of where we are now. Unfortunately, except in the case of Alaskan communications, it all means night, and most favorable conditions; and those who have to do with increasing the efficiency and range of the stations soon learn that the only thing to strive for is regular, reliable, daylight work between two given stations, winter and summer; and that reports of exceptional distances covered, wherein no time is mentioned, or whether by day or by night, are flat and uninteresting.

IMPROVEMENTS.

As fast as funds permit the following changes and additions are being made at stations:

(1) Substituting 500-cycle for 60-cycle transmitters.

(2) Increasing heights of masts and towers supporting aerials.

(3) Substituting steel towers for wooden masts in the tropics.

(4) Substituting flat-top aerials for umbrellas.

(5) Duplicating power units, to avoid probability of a complete breakdown of any station.

(6) Placing oil engines in fireproof buildings.

(7) Extension of the time-signal service and extension of all available land lines to each station.

(8) Furnishing two or three receivers, to be used in connection with "listening-in" devices.

NECESSITY FOR HIGH MASTS AND HIGH-FREQUENCY APPARATUS.

Referring to the first two improvements, just completed or now underway, for 27 stations, from certain experiments in long-distance sending and receiving, the Department's expert in wireless telegraphy, Dr. L. W. Austin, has deduced a formula for determining the possibilities of daylight communication between any two stations. He has shown that the principal factors which control the range of a station are the effective height of the aerial and the current in the aerial. Increasing heights of masts or towers of one station helps both sending and receiving. By increasing heights of masts of two stations by an equal amount, the strength of signal at the receiving station increases as the fourth power of the increase in height. Naturally, high self-supporting steel towers would be erected at all stations which might by any chance need to have a great range, were it not for the fact that high towers cost about $80 per foot, erected.

The range of a station increases with the current in the

aerial when sending. The high-frequency apparatus adopted as standard not only gives greater range, on account of increased radiation current obtained, but has the other advantages over the 60-cycle sets, of smaller damping; lower voltages with equal condenser capacity, or smaller condensers; and increased efficiency at the receiving end, due to the greater sensitiveness of the ear to the note of a 500-cycle spark, and the fact that the high note enables signals to be read through interference from the usual low note of the 60-cycle sets of ships and from the grating noise of static or atmospheric discharges. Static being far more troublesome in the tropics, high-frequency transmitters are much needed. Wireless communication between stations using low-frequency apparatus is often impossible for hours, and sometimes days, in low latitudes.

DUPLICATION OF POWER UNITS.

Whenever possible, a wireless station takes current from the neighboring town or power plant, and a kerosene or gasoline engine with an A. C. generator, chain driven, or a storage battery to run a motor-generator, constitute the breakdown service. At other stations duplicate engines, generators and transformers are furnished.

WHAT APPARATUS IS NEEDED.

There are numerous wireless problems unsolved; in fact, it might be said that we are still on the threshold of discovery in this field. The Navy's stations, ship and shore, should have the latest and most efficient devices, and it is the intention to continue to seek opportunities to test each new device which is developed and put it into use. A number of items which the Navy needs are mentioned. Some are said to be obtainable abroad and not in this country; some are about to become available; some are said to be in existence and use, but have not been offered; some are planned; some are partly

developed; some are promised for next week or next month, but the months succeed months and stretch into years. These are put down in haphazard fashion,—the order does not indicate their relative value for our purposes, nor the probability of obtaining them within a reasonable time.

(1) An amplifone, preferably one which is selective in itself.

(2) A light, portable, wireless set, 500 cycles or thereabouts, quenched gap, capable of giving two ampères in a suitable aerial, to operate on 110 or 125 volts D. C., using a commutator interrupter.

(3) Same to run on 10 to 20 volts, current to be supplied by portable storage battery.

(4) A light, satisfactory aeroplane set.

(5) A satisfactory 500-cycle, hand generator set.

(6) A small inexpensive set, power supplied by oil or gasoline engine, to give out a certain signal on a certain pitch at definite intervals, say once a minute, during a fog.

(7) Same, power supplied by hand.

(8) Satisfactory distant-control, quick-starting arrangements for kerosene and for gasoline engines.

(9) An American manufacturer or company who can deliver efficient modern wireless sets, 500-cycle, quenched gap, sizes 1, 2, 5 and 10 kilowatts, within six months.

(10) Same, 50 and 100 kilowatts.

(11) A wireless direction finder obtainable in the United States.

(12) A transmitter which will send in one direction only.

(13) A receiver which will receive from one direction only.

(14) A sensitive detector which will retain its sensitiveness indefinitely, and which can not be knocked out of adjustment by gun-fire and can stand nearby heavy sending and static.

(15) A wireless set which can be made to send either one of a number of pure musical notes at will, with a quick-change feature.

(16) A wireless telephone good for 12 miles over sea-water between modern battleships, which is reliable and easy to operate and keep in adjustment, and which cannot be interfered with.

(17) A secret-sending device, *i. e.*, one whose signals can be picked up by a special type of receiver, or are intelligible to the initiated, only. A new code is not wanted.

(18) Satisfactory means for substituting interrupted direct current for alternating current for wireless work, with 5 kw. sets and higher powers.

(19) A means of radiating energy for long-range wireless communication without the necessity for high towers.

(20) Any wireless device about which there is no question of patents.

No comment is required on many of these items. The fog-signal set is intended for use at all wireless stations and light-houses and on board light-vessels. A special aerial would give such a set a limited day range, say a range of five miles for a special aerial on a ship, and the ship in a fog hearing a signal would know that she was within five miles of a certain station. This information would be valuable in itself, and hearing the signals of two stations would indicate the ship's approximate position. Should a wireless signal and sound signal be made simultaneously, the difference of time between the two as received on board ship would give the approximate distance from the station. Two such distances and the course would enable the two positions to be plotted. Within a few years we shall have an easily-managed wireless direction finder, and in time navigators will be able to fix their position in a fog with sufficient precision for them to proceed with confidence. Suppose every ship were required to emit a certain signal to indicate her course in a fog, and to station a man, any man with good hearing, at a wireless receiver; even without a direction finder, the knowledge that there was another ship within five miles heading in a certain direction would be very useful.

CONCLUSION.

The future of the Navy's wireless telegraph system is bright. Our relations with the other departments of the Government are very satisfactory. Coöperation with the Weather Bureau of the Department of Agriculture in obtaining information concerning weather conditions at sea and distributing forecasts and storm warnings, improves in usefulness constantly. The War Department's Alaskan wireless stations and cables work satisfactorily with the naval wireless stations in handling official and commercial messages, and, in case of a breakdown of the Washington-Alaskan cable, the naval stations are prepared to handle the work of the northern part of the cable until repairs are made; and it is expected that in a few months they will be prepared to handle the work of the entire cable temporarily.

The Department of Commerce and Labor and the Navy Department work together to increase the safety of travel by sea, while everything possible is done to facilitate the splendid work done by the Revenue Cutter Service in succoring vessels in distress, and in guarding the Government's interests in Bering Sea, especially in connection with the protection of the fur-seal herd of the Pribilof Islands.

Wireless telegraphy is a subject which stimulates the imagination; and the necessity for a coast system under the control of the Navy Department for use in war, and its benefits to public and private interests in time of peace are so obvious that the coast signal service is confidently expected to increase in efficiency and importance at a rate equal to or higher than the best of the organizations which contribute to the people's safety and the general welfare.

FIREROOM, U. S. S. "CYCLOPS," SHOWING ASH EXPELLER.

NEW TYPE ASH EXPELLERS OF THE U. S. S. *CYCLOPS*.

By J. F. Metten, Associate.

Ash-handling gear has always been a prolific source of trouble to marine engineers, both in the Navy and the merchant marine, and the following description of a new type of under-water ash ejector installed on the 20,000-ton naval collier *Cyclops* may prove of interest:

The photograph was taken in the forward fireroom of the *Cyclops*, and shows the general appearance and space occupied above the floor plates. The drawing shows a cross section through the expeller, the essential feature of which consists of a tapered tube connecting a hopper located above the fireroom floor to the bottom of the ship. The lower part of the tube is formed with an annular chamber contracted at the lower end to form an ejector nozzle, a pump connection being provided above the inner bottom. At two points in the tube revolving gates are fitted, operated by a vertical shaft connecting to a crank at the hopper end. These gates are of circular form, and each is provided with a single opening of the same diameter as the tube. These openings are spaced so that the lower gate is open when the crank is in one extreme position against the stop, and the upper gate is open when the crank is in the other extreme position.

It will be noted that there is no continuous communication between the sea and hopper, and flooding of compartments is impossible. The discs are provided with about $^1/_{16}$-inch clearance, top and bottom, and are free to lift this amount, so they can make a comparatively tight joint with their upper faces when under any unbalanced pressure from below. The discs and shaft are supported on an adjustable cone step at

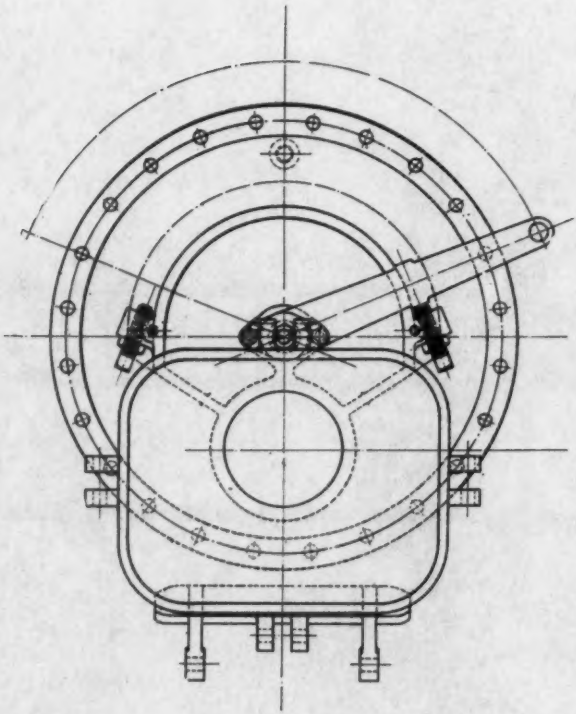
Fireroom, U. S. S. "Cyclops," Showing Ash Expeller.

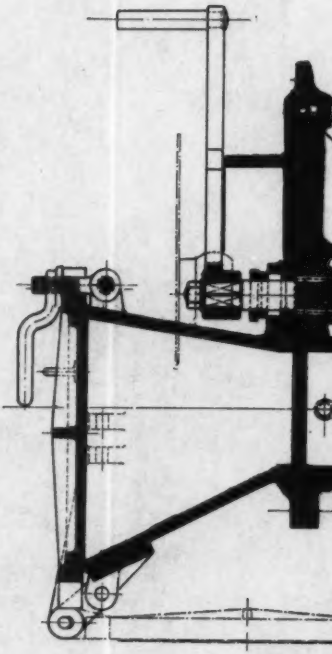
the bottom, which makes the operation of moving the discs an easy one, even with a charge of ashes in the tube. A small pipe is led to each gate, opposite the tube, through which a small stream of water is continuously supplied to keep both surfaces washed clean and to prevent the accumulation of fine ash in the clearance spaces. The top of the hopper is provided with the ordinary type of cover, secured by dogs, and is kept closed when the ejector is not in use.

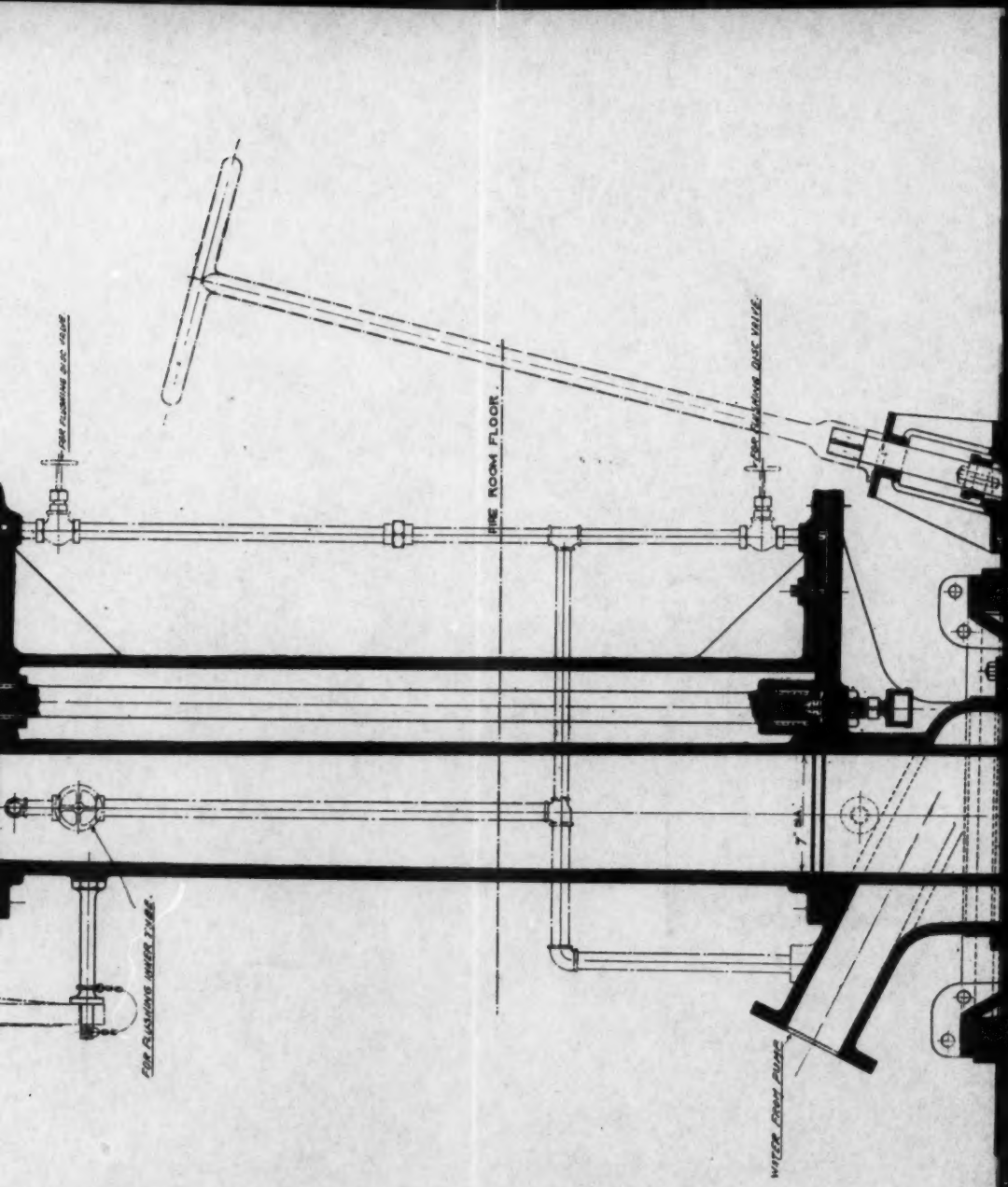
A special form of gate is fitted to the lower portion of the tube, which can be closed to permit overhauling the apparatus or replacing parts without docking the ship. The water is supplied through the annular nozzle under pressure, so that the kinetic energy of the issuing jet is considerably in excess of the static pressure at the mouth of the opening due to waterline head, which prevents any water entering the tube and also produces a slight vacuum to accelerate the discharge of ashes from the upper portion. Assuming the lower operating gate closed and the upper open, ashes are shoveled into the hopper until the tube fills nearly to the upper gate, when the handle is swung quickly against the opposite stop, closing the upper and opening the lower gate, which allows the contents to drop into the vortex of the annular jet and to be discharged into the sea. The operation is practically continuous, as ashes are shoveled into the hopper while the charge is being dumped, the latter requiring not more than a couple of seconds.

The ashes pass down the tube by gravity, so there is none of the rapid wearing that is experienced when they are forced through at a high velocity by water or compressed air. The annular jet also forms a protecting ring at the lower part of the opening and prevents any wearing at this point, as all the discharged material passes out through the center of the jet. These ejectors have been in use on the *Cyclops* over a year without requiring any parts, and are reported as showing no appreciable signs of wear, which is unusual for apparatus of this kind.

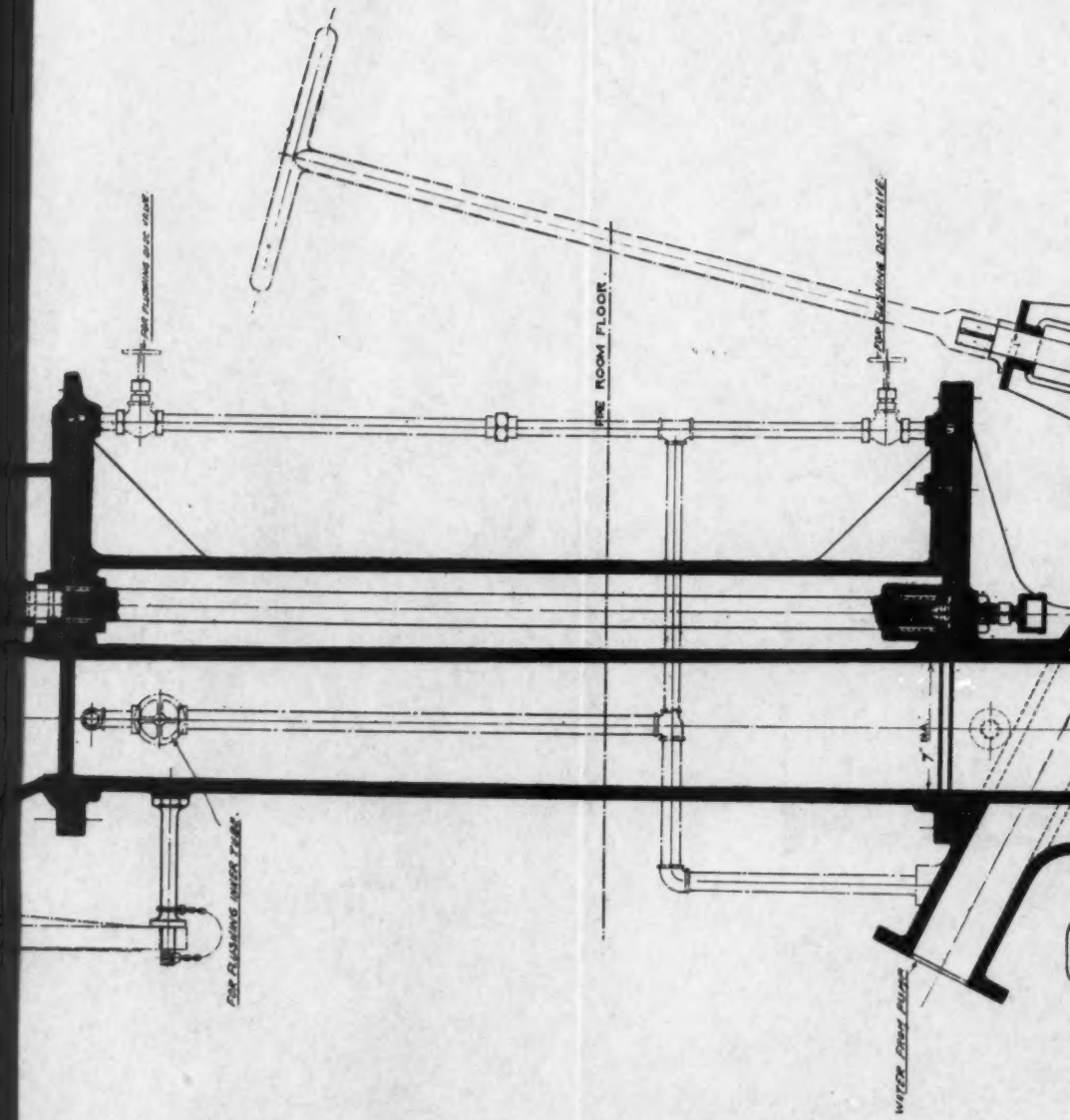
In addition to the non-wearing qualities, the use of the







ASH EXPELLER, U. S. S. "CYCLOPS."



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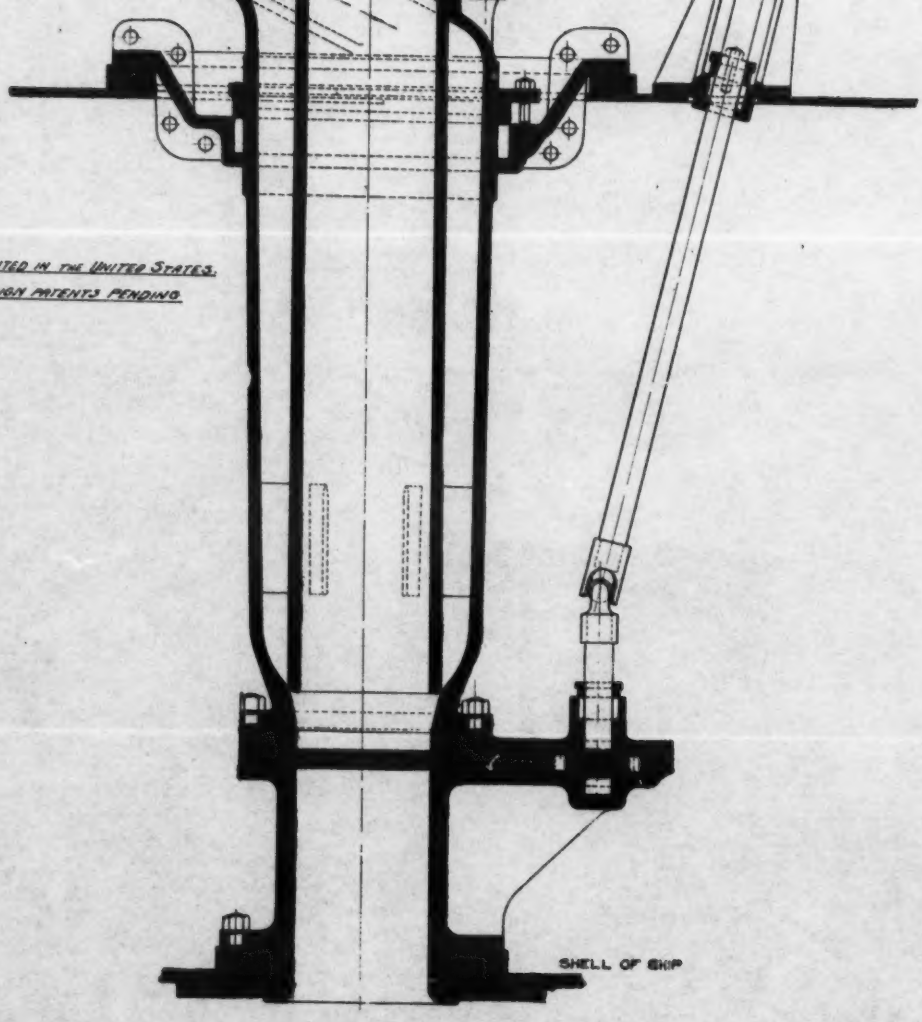

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FOREIGN PATENTS PENDING

annular jet is intended to insure the ash and clinker being carried well away from the bottom of the ship, to prevent the tendency for fine ash to be rapidly carried back to the surface, as has been experienced when using compressed air as the discharging medium. The pressure required on the expellers of the *Cyclops,* operating at the load draught of 28 feet, was about 60 pounds per square inch, and was supplied by a small DeLaval turbine-driven centrifugal pump.

Inasmuch as the passage from the hopper to the outlet is of uniformly increasing cross section, it is not necessary to provide any mechanical crusher, as lumps of clinker or other objects that will pass through the throat of the hopper will not fail to be discharged. Large pieces of clinker are broken with a shovel before going into the hopper, the same as when using the ordinary above-water hydraulic ejector. With one man operating the lever controlling the gates, ashes can be discharged as fast as two men can shovel into the hopper.

At the conclusion of the *Cyclops'* preliminary official trials the trial board carried out a test on one of her ejectors, in which wire nails, glass, tin cans, etc., were mixed with ashes and successfully discharged, even coal bags being passed through without difficulty. Should the tube become stopped by any bagging or similar material, it can be blown out by closing the hopper cover and turning water from the jet supply into the tube below the upper gate. In ordinary service this is seldom necessary.

Extensive experiments have recently been carried out with the view of ascertaining the best nozzle form, and the results show that considerably less power is required to operate this type than the ordinary ejector, particularly for deep-draught ships. The water supply for ejectors of the latter type on a ship of 30 feet draught must be under a pressure of from 250 to 300 pounds per square inch, and to maintain this pressure on a ¾-inch diameter nozzle requires from 40 to 48 water horsepower. With the best form of annular jet, as determined by experiments mentioned above, it has been found possible to operate an expeller of the *Cyclops* type,

having a 7-inch diameter tube, under a head of 30 feet with 27 water horsepower and a pressure of 50 pounds per square inch.

What is believed to be an important feature in connection with this apparatus, particularly for naval work, is that the pumps are of such a character as to be suitable for drainage work; thus the pump supplying ash ejectors for each fireroom compartment could also be provided with supplemental bilge-suction and overboard-discharge pipes so as to be available for drainage work in an emergency. As a matter of fact, it is a common practice in foreign war vessels to provide independent drainage pumps in each compartment, which could be made available for supplying the ash ejectors described above.

TESTS OF OIL BURNERS.

By Angelo Conti.

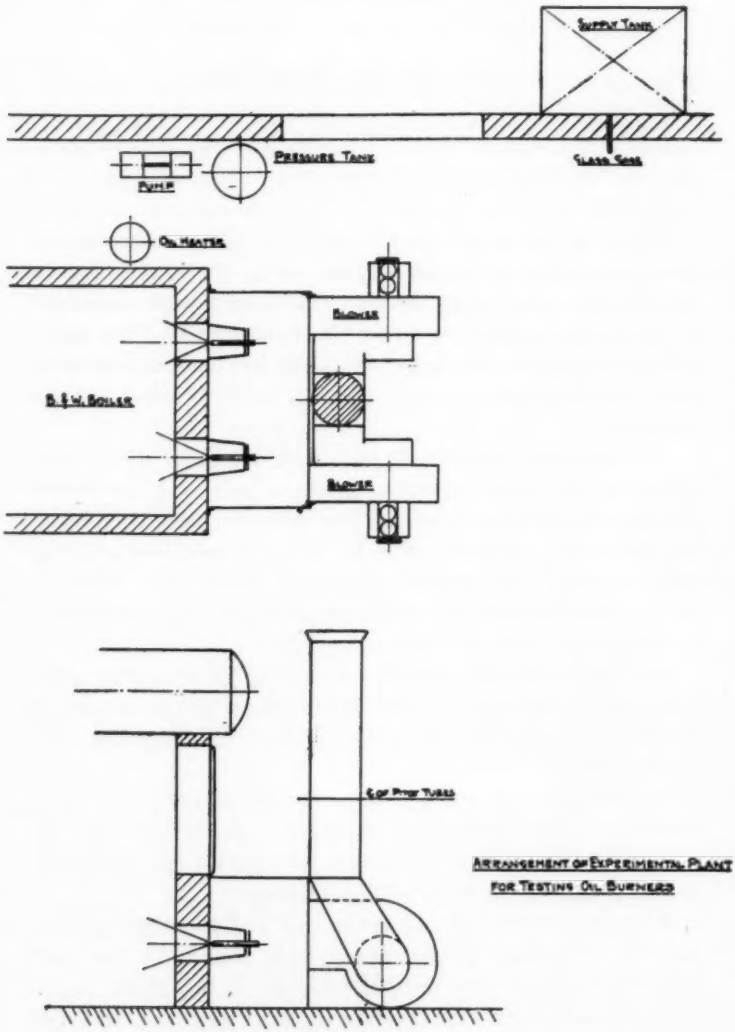
Following the award of a contract for the construction of two oil-burning destroyers for the U. S. Navy, the *Perkins* and *Sterett,* some experiments on oil burners were conducted at the works of the Fore River Shipbuilding Co. The burners experimented with were all of the mechanical atomizing type, as illustrated in the August, 1911, number of the Journal.

The tests were carried out on a B. & W. boiler of the land type, used for experimental purposes, a unit of 1,956 square feet heating surface, 43 square feet grate surface, when burning coal, and equipped with B. & W. superheaters giving approximately 100 degrees superheat when the boiler is generating 6,000 pounds of steam per hour (rated capacity) at 250 pounds gage pressure.

The boiler was adapted for oil burning by removing grate bars and furnace doors, the lower front being completely blanked with a brick wall having two circular openings for the burners.

An airtight steel casing, enclosing the burners, was fitted in front of the boiler, and pressure raised within by two independent steam-driven blowers, of Sturtevant make, discharging directly in front of the housing.

A supply tank of rectangular section and about 600 gallons capacity (running approximately 68.5 pounds to the inch from calibration) was located outside of the boiler room. The oil used from this tank during each test was observed through a glass gage, and the weight calculated from the observed volume and the specific gravity obtained with a very sensitive hydrometer.



Arrangement of Experimental Plant for Testing Oil Burners

Fig. 1.

A horizontal duplex pump drew through a strainer from the supply tank, and delivered the oil at the bottom of a pressure reservoir of about 100-gallon capacity, fitted with a spring-loaded valve which could be set at any desired pressure.

Thence the oil flowed through a heater to the boiler.

Steam for the auxiliaries was taken from the power-house line, so that all the steam generated by the boiler could be turned into the condenser of the experimental turbine plant and measured by the weighing tanks.

During all tests care was taken to keep a constant level on the glass gage by regulating the feed supply, and, to avoid the possibility of errors due to leaky valves, all experiments were run as nearly as possible to the working pressure of the power house.

The experiments conducted can be grouped as follows:

1st. Preliminary tests with two burners of varying capacities, to determine the proper size of bore.

2d. Miscellaneous tests with one burner, to determine the most efficient operating conditions.

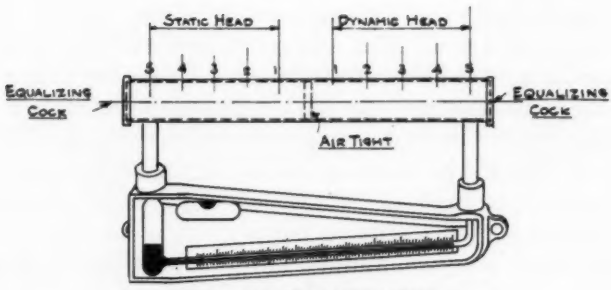
3d. Capacity tests of a large number of single burners, previous to their installation aboard ship.

On some of the tests of the second group and on all the tests of the third means were provided to measure the amount of air supplied to the burners. A vertical, belled-top intake pipe, 24 inches in diameter, 15 feet long, was erected over the housing, and the bottom was shaped to enclose the inlet opening of each blower.

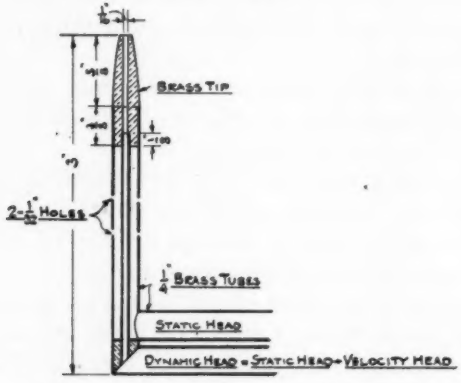
The total output of the two blowers was measured by observing the velocity head of the air flowing through the intake pipe by means of five pitot tubes arranged as shown.

The use of more than one tube was at first deemed advisable, owing to the possible whirling of the air, but experience showed that in each test readings of all outside tubes to be practically the same, the center tube only usually reading a little higher.

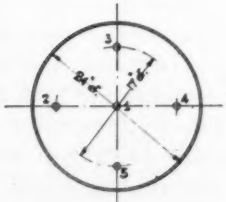
The two branches of each tube were connected by means of rubber hose to a small two-part reservoir, each branch



INCLINED DIFFERENTIAL GAGE



PITOT TUBE



LOCATION OF PITOT TUBES IN INTAKE PIPE

Fig. 2.

being supplied with a cut-out cock bearing the tube's number as shown. This reservoir was connected to an inclined gage filled with a non-drying and non-evaporating oil of constant specific gravity, so designed that the reading represented a head of distilled water in hundredths of an inch. This instrument is manufactured by Charles J. Tagliabue, of New York. Readings were taken from one pitot tube at a time by opening the cut-out cock of the same number, care being taken to equalize the pressure in the reservoir before shifting to the next tube.

The static pressure in the housing was observed by means of two U tubes located one on each side.

The velocity of the air flowing through intake pipe is expressed by the formula $V = 60\sqrt{2gH}$, where H is the head in feet of the equivalent volume of air and $g = 32.16$. One inch of water is equivalent to 5.2 pounds per square foot.

$$H = 5.2\,\frac{\text{velocity head inches of water}}{\text{weight of 1 cubic foot of air}} = 5.2\,\frac{h}{p}.$$

Substituting

$$V = 60\sqrt{5.2\,\frac{2gh}{H}} = \text{velocity constant}\,\sqrt{h}.$$

P is the weight per cubic foot of air in the pipe. Its value depends upon pressure, temperature and humidity, as expressed by the formula:

$$P = \frac{.080723}{1 + .0020389(t + 32)} \cdot \frac{b - 378\,e}{29.921}.$$

Where t is temperature degrees F., b is corrected height of barometer in inches of mercury, and e is the pressure due to the vapor in the air, also in inches of mercury.

As the variation of density with humidity is very small it is possible to assume a constant humidity and plot contour

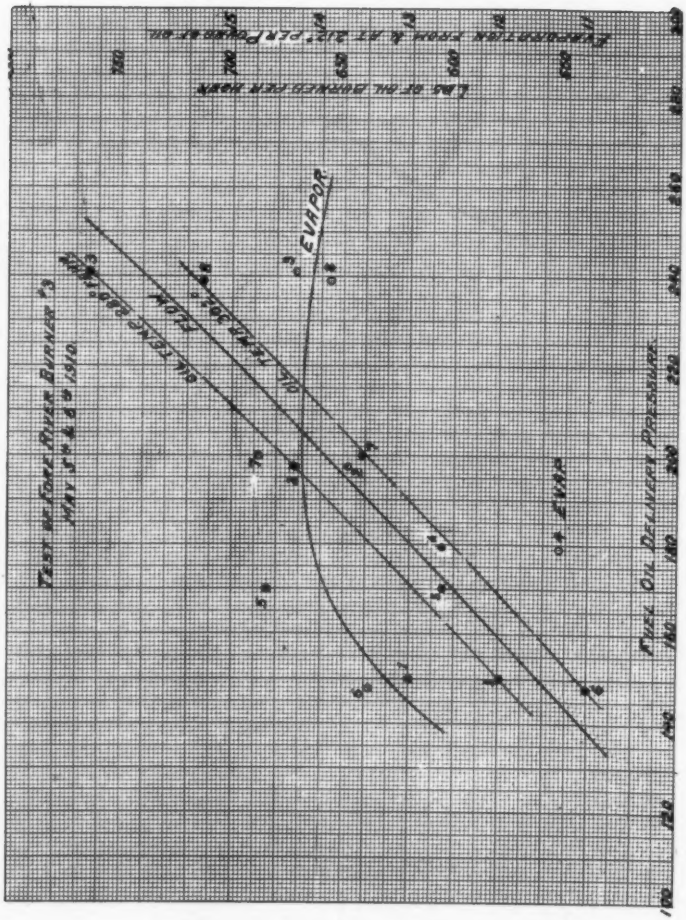

Test of Foos Oven Burner C3
May 3rd & 4th 1910.
Oil Temperature
Oil Temperature
Evapor
Evapor
Fuel Oil Delivery Pressure
Lbs. of Oil Burned per Hour
Evaporation from & at 212° per Pound of Oil

Fig. 3.

curves of weight per cubic foot of air upon barometric pressures and temperatures. For these curves we shall refer to a paper on "Experiments with Ventilating Fans and Pipes," published by Naval Constructor Taylor, U. S. N., in the 1905 "Transactions of N. A. and M. E."

These curves give the weight of a cubic foot of air, assuming a constant humidity of 70 per cent. and is amply sufficient for practical puposes.

In the formula b is the barometric pressure corrected to the static pressure of the air in the pipe, but, as this correction is negligible, the air within the pipe is assumed to have the same barometric pressure as the atmosphere. Therefore, in order to obtain P from the curves referred to, it is only necessary to correct the barometer to the temperature of the air observed in the intake pipe. Early experiments soon brought out the importance of reducing the air supply to a minimum, and, accordingly, on each test the blowers were regulated so as to run with a slight haze of smoke.

Experiments of the third group, with one burner at a time, gave the following results:

Average of.....	20 burners.	56 burners.
Diameter of bore, inch.....	0.0935	0.099
Flow, pounds per hour.....	604	725
Oil pressure at burner, pounds gage	200	200
Oil temperature at burner, degrees	300	288
Air pressure in housing, inches	1.19	1.73
Cubic feet of air per pound of oil	296	310

Each burner was tested for a period of about 30 minutes and no attempt was made to measure the evaporation. While the observed quantities of air supplied to the burners closely approached average figures used in practice they are thought to

be slightly in excess, owing to some minor unavoidable leaks around the housing.

Standard Oil Company's oil was used for the tests of the 1st group, but the remaining tests were run on Texas oil which gave the following analysis:

Fire test, degrees F	290
Flash test, degrees F	206
Gravity Baumé, degrees	29.7
Specific gravity	0.876
B. T. U., per pound	19,374
Sulphur, per cent	0.17

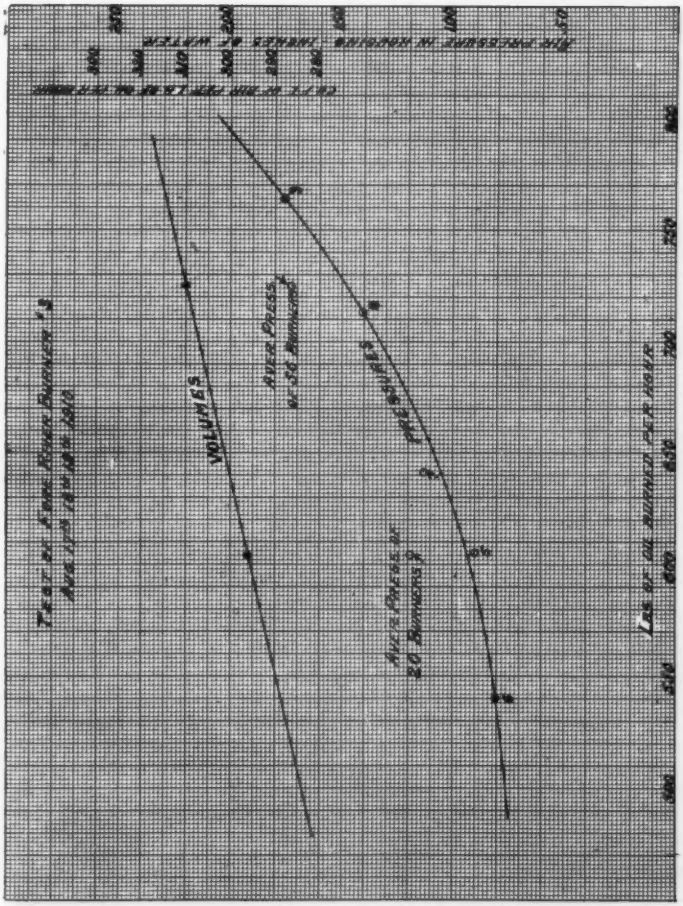
TESTS WITH TWO OIL BURNERS, FORE RIVER TYPE, WITH STANDARD OIL COMPANY'S OIL, OCTOBER, 1909.

Duration of tests	1 hour.	1 hour.	1 hour.	1 hour.	1 hour.
Steam pressure at boiler, pounds gage	90	94	97.5	96	102
Steam temperature at boiler, degrees F.	347	351	361	...	...
Temperature of saturated steam, degrees F.	331	334	336	...	...
Superheat, degrees F.	16	17	25	...	...
Temperature of feed water, degrees F.	115	112	110	106.5	105
Factor of evaporation	1.148	1.132	1.16	1.148	1.151
Water evaporated per hour, pounds	10,184	11,313	12,867	10,143.5	14,980
Oil burned per hour, pounds	942	1,023	1,231	937	1,382
Actual evaporation per pound of oil	10.80	11.07	10.44	10.83	10.83
Evaporation from and at 212 degrees F. per pound of oil	12.40	12.75	12.10	12.43	12.48
Steam to oil heater, pounds gage	118	118	118	118	118
Temperature of fuel oil leaving heater, degs. F.	312	304	295	293	280
Fuel-oil pressure at burners, pounds gage	225	220	210	230	227
R.p.m. of blowers	590	580	757	650	880
Air pressure in housing, inches of water	1.00	1.00	1.75	1.54	2.77

TEST OF OIL BURNER NO. 3, FORE RIVER TYPE. KIND OF OIL USED: TEXAS OIL.—MAY, 1910.

Object of test: To determine most suitable delivery pressure.

Number of test	6	1	5	4	2	7	8	3
Duration of test	1 hour.	1 hour.	30 m.	1h.24m.	36 m.	1 hour.	1 hour.	1 hour.
Steam press. at boiler, lbs. gage	114	112	115	114	110	114	114	114
Steam temp at boiler, degrees F.	427	463	444	488	464	439	452	457
Temp. saturated steam, degs. F.	347	345.6	347.4	347	344	347	347	347
Superheat, degrees F.	80	117.4	96.6	141	120	92	105	110
Temp. of feed water, degrees F.	102	104	109	101	102	105	100	97.5
Factor of evaporation	1.19	1.22	1.2	1.232	1.228	1.202	1.215	1.22
Water evaporated per hour, lbs.	6108,5	6187.5	7372	5570	7600	7856.5	8163.5	8948
Oil burned per hour, pounds	540	579	605	605	682	641	713	764
Actual evaporation per lb. of oil	11.3	10.65	12.15	9.2	11.15	12.25	11.45	11.7
Evaporation from and at 212 degrees F. per pound of oil	13.45	13.0	14.6	11.33	13.7	14.7	13.9	14.3
Steam to oil heater, pounds gage.	116	116	111.5	112	117	114	116	116
Temperature of fuel oil leaving heater, degrees F.	304	290	296	291	286	299	302	288
Fuel-oil press. at burners, pounds gage	148	150	170	179	197.5	200	239	241
R.p.m. of blowers	533	628	555	1000	670	631	700	652
Air press. in housing, ins. water	0.8	1.6	0 9	4.1	1.72	1.15	1.4	1.75
Stack temperature, degrees F.	445	...	490	590	...	500	530	...


VOLUMES
Fig. 4.

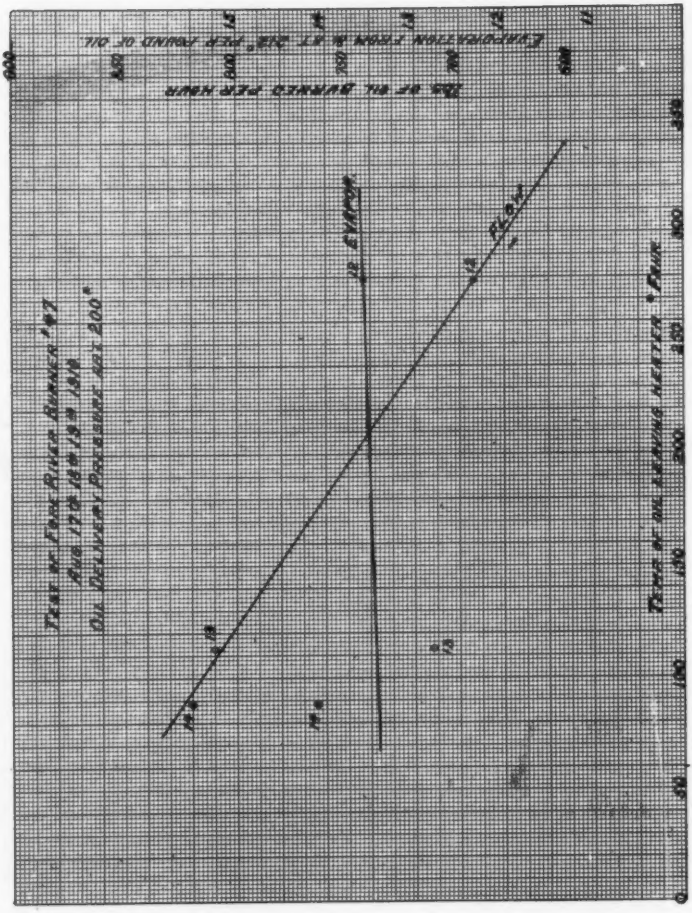


Fig. 5.

TEST OF OIL BURNERS, FORE RIVER TYPE. KIND OF OIL USED: TEXAS OIL.

Object of test: (July) To determine the influence of throttling the burner; (August) To determine the influence of heating the oil on efficiency.

	42		47		
	July, 1910.		August, 1910.		
Oil burner number (1 burner in operation)					
Date of test					
Duration of test	2 hours	2 hours	1 hour	2 hours	1 h. 30 m.
Steam pressure at boiler, pounds gage	102.25	96.0	110.5	113.6	116.0
Steam temperature at boiler, degrees F	438.5	420.0	468.0	485.5	489.4
Temperature of saturated steam, degrees F	339.5	335.4	344.5	346.4	347.7
Superheat, degrees F	99.0	85.0	123.5	139.1	141.7
Temperature of feed water, degrees F	116.0	125.0	122.0	122.0	124.3
Factor of evaporation	1.195	1.178	1.202	1.21	1.21
Water evaporated per hour, pounds	8,409.0	5,135.0	7,844.0	8,574.5	9,550.0
Oil burned per hour, pounds	* 718	§ 461	694	810	820
Actual evaporation per pound of oil	* 11.7	§ 11.13	11.3	10.58	11.64
Evap. from and at 212 degs. F. per lb. of oil	* 13.98	§ 13.1	13.6	12.8	14.1
Steam to oil heater, pounds gage	* 120	§ 115	115	...	...
Temp. of fuel oil leaving heater, degrees F	* 281	§ 290	279	133	88
Fuel-oil pressure at burners, pounds gage	200	200	200	195	190
R.p.m. of blowers	900	...	836	1,016	868
Air pressure in housing, inches of water	1.8	1.15	1.13	1.6	1.18
Veloc. of air through intake pipe, ft. per min.	1,225	1,044	...	...	...
Cubic feet of air per minute to blower	3,850	3,260	...	...	...
Cubic feet of air per pound of oil per hour	321.5	427	...	...	...
Stack temperature, degrees F	590	504	650	700	678

* Burner wide open. § Burner throttled.

NOTES.

THE CORROSION OF BRASS, WITH SPECIAL REFERENCE TO CONDENSER TUBES.*

By PAUL T. BRÜHL, M. Sc., Bowen Research Scholar, University of Birmingham.

The corrosion of brass condenser tubes may conveniently be classed under four heads:

(1) Corrosion proper; where the metal is uniformly removed over the whole surface.

(2) Dezincification; where the zinc being preferentially more rapidly removed than the copper, the surface of the metal becomes copper-rich in places. The action does not usually extend much below the surface, although it may occasionally be so marked as to result in copper "plugs."

(3) Pitting. This is by far the most serious form of corrosion, as it considerably curtails the life of the tube. It is due to galvanic action between the deposit on and the metal of the condenser tube. It may occur in any portion of the tube, that is to say, in the roof and sides as well as along the floor. It most often occurs in the lowest portions of the tube because of the natural downward gravitation of any extraneous sediment, or of any insoluble product of corrosion.

(4) Erosion. Here the mechanical influence of the stream of cooling water comes into play. Its effect is small and, under ordinary circumstances, uniform.

Examination of Some Corroded Specimens of Condenser Tubing.—The following description of five selected cases may serve to illustrate the effects observed in practice. The samples were supplied through the kindness of Engineer Vice Admiral Sir H. Oram.

* Institute of Metals. Abstracted.

Specimen 1.—This tube, four years old, was situated in the eighth row from the top; the water circulated through the tube, and, entering at the bottom of the condenser, discharged at the top. The quality was a 70/29/1. Serious pitting, which in places had pierced the tube, had occurred, the pits being roughly funnel-shaped, with the larger diameter on the water side. Besides the usual corrosion products, both iron hydrate and insoluble matter were present. Specks of spongy copper were common. The pit was not infrequently filled up by the deposit.

Specimen 2.—The tube (70/29/1) was seven years old, and taken from the bottom row. The circulating water passed through the tube entering at the top of the condenser. The deposit was principally the green basic chloride. Dezincification was not pronounced for the luster of a freshly scratched surface was quite normal; the interior surface of the tube was smooth, and one small hole only had formed along a line of season cracking.*

Specimen 3.—The tube was a 70/29/1, two years old, and taken from the sixth row from the bottom of the condenser. The circulating water was outside the tube, the inlet being at the bottom of the condenser. The deposit was dark brown in color, the green oxychloride being practically absent. The edges of the pits seemed to be somewhat steeper than in the two preceding instances.

Specimen 4.—The tube—70/29/1—was five years old, and taken from one of the top rows of the auxiliary condenser. The circulating water passed through the tubes, entering at the bottom and discharging at the top. There was very little deposit and no pitting, the tube having been rejected because of incipient season cracking.

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*Season cracking is attributed to excessive work with insufficient annealing. The resulting strained condition of the crystals leads in time to a split. According to the "Brass World" it is due, in most cases, to the contact of the brass tubes either with ammonia water or with substances of which it is a product of decomposition. Hard-drawn, seamless tubing—66 per cent. copper, 34 per cent. zinc—was seriously affected by ammonia water, the fracture along the split being strongly crystalline. Professor Carpenter regards the cracking as due to the gradual change of the unstable β into the brittle $\alpha + \gamma$. Perhaps some rough handling of the tubes when in the neighborhood of the critical temperature—470 degrees Cent.—as may well occur during annealing, may act as a predisposing cause to season cracking.

Specimen 5.—The tube—70/29/1—four years old, was one of a number removed at random from the condenser for inspection. The circulating water passed through the tubes, entering at the bottom and discharging at the top. The deposit was rich in iron hydrate and poor in the basic chloride. Dezincification was marked.

The examination of these tubes seemed to show that iron hydrate is by far the most injurious constituent of the deposit, being more electro-negative than cupric oxide and the basic chloride. Specimen 1, which had a deposit assaying 8.6 per cent. ferric oxide and 0.27 per cent. insoluble matter, was much more pitted than Specimen 5, which gave the values 1.5 per cent. and 0.41 per cent. for the same impurities. Tube 2, which had been in use for seven years, was hardly affected at all, though well covered with a thin film of the green oxychloride.

Suggested Remedies.—A remedy which suggests itself immediately is the use of some protective coating, which should be electro-negative preferably to iron hydrate. Tinning is certainly useful, though by no means a sovereign remedy, because the layer of tin is not always intact. The application of a coating of iron oxide by the method suggested by Mr. Uthemann is excellent so long as it affords complete protection over the entire surface. But the method appears somewhat risky, as any discontinuity would only aggravate the evil it was intended to counteract.

Another coating is that suggested by B. Mullauer. It is the oxide formed in copper or brass by heating a 5 per cent. sodium hydrate solution to 100 degrees C., and adding 1 per cent. potassium persulphate. The article to be coated is immersed in this bath and kept moving to and fro. The deposit so obtained is said to be strongly adherent, but was found to scale off in sea water after some four weeks. Its protective action, even when the coating was intact, was not very apparent. The plates showed no signs of any action for three or four days, after which the green oxychloride was slowly formed.

T. B. Allen heats the metal in contact with silicon to a temperature below the melting points of either in a non-oxidizing atmosphere. An alloy of silicon and the metal is thereby produced on the surface, which is then said to be more corrosion proof.

On the whole, however, the question of lessening corrosion by protective coatings does not promise to be of economic usefulness in the case of condenser tubes. The line along which future investigation ought to be made is the study of the alloys of brass with one or even more other substances, with a view to obtaining a mixture which will give the requisite mechanical properties, and, at the same time, be the least influenced by sea water. Were there no reasons against the circulation of the cooling water along the outside of the tubes, the use of zinc, as has been pointed out by Bengough, might at once put an end to the trouble. The addition of 1 per cent. tin, as in the usual Admiralty specification, does not appreciably affect the electromotive force. Its protective action probably depends on the comparatively inert tin oxide produced. The principal evils to be contended against are iron hydrate and carbonaceous matter. It is admitted that vessels which spend the greater portion of their time at sea beyond the limits where town sewage and river dirt contaminate the water experience fewer troubles from pitting than vessels which ply up and down foul rivers. It follows that the marine engineer should make a point of flushing out his condenser with clean water on arriving in port. The iron hydrate is derived no doubt from the cast-iron end cover and the inlet pipe, although scale may be drawn in with the cooling water. It would therefore appear advisable for the end cover and inlet pipe to be made of brass.* Further, the use of some form of filter for the incoming water would be advantageous. Of these filters many forms are on the market, and some in actual use in electrical installations, which obtain their water supply from dirty canals.

Effect of Strain.—The irregular distribution of strain on

* Although the author is aware that the British Admiralty hold strongly to the view that cast iron is best suited for the manufacture of the end covers.

any metallic surface gives rise to differences of potential. In order to investigate this point short lengths were procured of condenser tubing of the following compositions:

	Per cent.		Per cent.
Zinc	30	Zinc	29
Copper	70	Copper	70
		Tin	1

These lengths were wiped down with cotton waste and then dipped into potash and clean water to remove any adherent grease. The potential differences of the two ends were next immediately ascertained by comparison with a standard electrode. The electrolyte used was synthetic sea water of the following composition:

	Per cent.
Sodium chloride	2.7
Magnesium chloride	0.36
Magnesium sulphate	0.23
Calcium sulphate	0.14
Potassium chloride	0.07

As a result of the tests, it was found that no tubes showed a difference of potential between the two ends of more than 0.0002 volt. It was noticed that when a comparatively slight strain was put on such a tube, as by gentle polishing with emery paper, the result was an appreciable rise of potential, which tended to reach a maximum with further polishing. The solution pressure of tubes of the 70/29/1 mixture was very similar to that of the 70/30. The above experiments proved a condenser tube does exhibit differences of potential along its length; but these differences are not sufficiently large and abrupt to explain any corrosion other than a more or less uniform one extending over the whole surface.

The Effect of Crystal Size.—To test the influence of crystal size on the rate of corrosion, six 70/30 plates were taken in the hard-rolled condition, three of them being then annealed at 700 degrees C. for ten minutes, the other three at

the same temperature for three hours. By this means two sets of plates were obtained, one with small crystals, the other with crystals very much larger, and as both sets were cut from the same strip, they were, of course, of identical composition. After thorough cleaning with dilute sulphuric acid and emery paper, the plates were weighed and immersed in synthetic sea water, which was kept stirred on an average for ten hours a day. The loss in weight during the first six weeks shows on the whole that a small crystalline structure is conducive to more rapid corrosion, but after some twelve weeks the small crystalline plates, which had hitherto corroded faster, commenced to lose weight more slowly than the large crystalline plates. It would be interesting to ascertain the reason for such a change. The method of manufacture of condenser tubes does not permit of serious variations in the crystalline structure, and therefore crystal size plays a very insignificant part in the problem of corrosion.

Effect of Different Annealing Temperatures.—In order to obtain information on this point, three specimens of 70/30 brass were annealed in an electric furnace and slowly cooled. The figures show that corrosion increases with the temperature of annealing. It is not good, therefore, for the final annealing in the manufacture of condenser tubes to be unduly long.

Effect of Rolling.—Brass, on rolling, becomes more electro-positive, or, in other words, more liable to corrosion than the soft metal. The energy imparted is partly evolved as heat and partly stored up in the metal as a kind of potential chemical energy; rolling results in the production of an amorphous modification which is electro-positive to the crystalline metal, and the resultant voltaic effect causes more rapid solution.

To test the effect of rolling, three plates of 70/30 brass were hard rolled to different extents and then immersed in sea water.

Plate H_1 was 0.1 inch thick.
Plate H_2 was 0.0875 inch thick.
Plate H_3 was 0.075 inch thick.

The loss in grammes per square inch surface was as follows:

Time, in weeks.	H_1.	H_2.	H_3.
0-2.....	0.0049.....	0.0053.....	0.0058
0-3.....	0.0053.....	0.0057.....	0.0062
0-6.....	0.0083.....	0.0085.....	0.0092
0-9.....	0.0098.....	0.1010.....	0.1070

The figures show clearly how the rate of corrosion increases with the amount of work. If we take a strip of brass bent over in the shape of a U, with one limb hard rolled and the other well annealed, and immerse it in dilute HCl, bubbles of hydrogen will be disengaged at the cathode, *i. e.*, on the annealed limb. After some hours the hard-rolled limb will be practically dissolved away, whilst the other will have been markedly less attacked. At the junction of metal and liquid corrosion will be very pronounced, the brass being eaten through in a succession of perforations similar to the edges of a postage stamp.

In view of the more rapid corrosion of hard-rolled metal, it would appear advisable, considering the thinness of the tube wall, that the last pinch in the drawing of condenser tubes (after the final annealing has been performed) should be as small as possible.

Experiments on the Corrosion of Annealed 70/30 Brass Under Different Conditions.—A series of experiments were undertaken to test the rate of corrosion under varying conditions, such as are met with in practice.

The results leave no doubt that a rise of temperature up to a certain extent is favorable to corrosion, as it increases the reaction velocity between the brass and the sea water. An increase in the quantity of dissolved air also promotes chemical activity.

The supply of sea water was changed every third week. Corrosion during this period was most marked just after such renewals, the reaction velocity being proportional to the con-

centrations of the salts dissolved in the sea water. As the concentrations must diminish with time, the rate of corrosion, other conditions being constant, must gradually diminish.

If predictions based on the constitutions and electromotive forces of the two metals were to be made, one would certainly think that Muntz metal, by virtue of its dual structure and higher electromotive force, would be more liable to corrosion than copper. As a matter of fact, such predictions would not be entirely correct. Muntz metal corrodes somewhat more than twice as fast as copper during the first week of immersion in sea water. This may naturally be expected. Why, then, does copper corrode more rapidly with further lapse of time? The most apparent cause is found by an examination of the specimens. Copper exhibits a tendency to peel, thereby incurring a mechanical loss in the first place and a chemical one in the second by the continual exposure of fresh surfaces. Muntz metal, on the other hand, shows no such tendency, although the surface becomes roughened by the unequal rate of attack of the α and β constituents. The peeling is certainly not due to any strained condition of the surface, as the copper was annealed before use. Another explanation of the greater durability of Muntz metal is that the oxide film which forms on it is a mixture of the oxides of copper and zinc, whilst the film that appears on copper is cuprous oxide. Zinc oxide is very much less harmful electrochemically than cuprous oxide because of its smaller difference of potential and higher specific resistance. Further, as the oxide film forms the cathode, hydrogen will be evolved at such negative areas; cuprous oxide is in all probability reduced by nascent hydrogen at the temperature of the condenser tube, *i. e.*, 40 degrees C.; that it is comparatively easily reduced is seen by the fact that ordinary hydrogen reduces it at 155 degrees C. The reduction of the cuprous oxide may explain the peeling referred to above.

Effect of Oil.—The oil used in the lubrication of the piston and slide valves should be composed of hydrocarbons only—

that is to say, it ought always to be of mineral origin. It is not advisable to employ organic oils for the purpose, as they possess more body at high temperatures than do the previous class. They are subject, on the other hand, to partial decomposition in the presence of steam, giving rise to glycerine and free acid, which latter becomes a serious danger when in contact with the wall of the condenser tube. Any oil which may find its way into the condenser does so in the form of vapor, owing to the temperature in the cylinder and the continuous rush of steam from it. In the condenser the oil condenses on the tubes in the form of minute globules, which give rise to irregular corrosion.

Effect of Stray Electric Currents.—There can be no doubt that stray currents of electricity escaping from imperfect fittings increase the rate of corrosion of condenser tubes by increasing the velocity of removal from the solution of the charged ions. Troubles from this source not infrequently arise both on ships using continuous current to a great extent, and in tramway generating stations, where the negative pole is earthed. On this subject Mr. Milton, writing on the decay of metals, says:

"If, for instance, there is a leakage from the positive cable in such a position that part of it proceeds to the sea (earths) through the water flowing through the condenser tubes, which are, of course, clean metal, instead of through the hull of the vessel, which is kept painted in order to prevent any actual contact between the iron and the sea water, some electrolytic action must take place in the tubes themselves."

The prevention of corrosion from this source can be effected by providing a good path for the stray currents outside the condenser.

"This may be done by making a connection between the condenser-tube plates, the cooling-water inlet, the outlet piping, and the air-pump suction piping by means of a large cable which need not be insulated, so that the condenser is, so to speak, short-circuited. As a rule, the locality of the stray currents can usually be accurately determined by careful volt-

age measurements, and the most suitable points for the connection of the short-circuiting cable chosen accordingly."

The importance of stray electric currents on corrosion is further emphasized by the instance cited by another writer, who states that two water pipes, each close to an electric lead, were eaten right through in small holes, apparently punched out of the metal.

The thickness of the deposits on a condenser tube is small, and as the specific resistances are not of a high order, little opposition will be offered to the passage of an electric current; hence we may suppose that all the products of corrosion, when wet, set up electro-chemical action with the brass. From a consideration of the tests made of the relative position in an electro-chemical scale it was seen that the most dangerous substances are carbon, cuprous oxide and iron oxide. Iron hydrate and the oxychloride promote chemical action by the absorption of oxygen.

Polarization and Depolarisers.—By the passage of an electric current from brass to any of the corrosion products resting on it hydrogen is evolved at the cathode, and being a high insulator it will tend, unless removed, to stop any further action. The cathode is said to be polarized by the hydrogen, but as there is always a certain amount of oxygen dissolved in sea water, the hydrogen will be oxidized and removed to some extent. In the case of a condenser tube, polarization is very unlikely, as the bubbles of hydrogen are mechanically removed by the swirl of water. Some experiments were carried out to study the rate of polarization in still water, and a couple of typical curves are given. They show that the substances considered act as depolarizers in a small way by absorbing the hydrogen, but the current which can pass would eventually be very slight.

The localities of pits.—A point of interest and importance is the consideration of the circumstances which go to determine the localities where pitting will take place. In the case of 70/30 brass these localities cannot be supposed to depend upon

the distribution of any segregated impurity. In fact, as has been pointed out, the presence in brass of free lead or tin, or in fact of any phase besides the α phase, would not, *ipso facto*, lead to an increased rate of corrosion, sea water being the electrolyte. The use of acid completely alters the conditions under which the metal is being destroyed. Here no film can form on it, owing to the solvent action of the acid, and the effect of the products of corrosion on the metal—which is of very considerable importance—is altogether lost. Therefore it follows that in corrosion experiments it would be better not to use an accelerator.

The positions of the more serious pits are probably governed by two factors—the presence of mechanical defects such as "spills," and of certain deposits. Even a comparatively small spill in the tube wall will result, when the cooling water ceases to be pumped through, in the formation of a little reservoir, to which air has complete access. It is precisely under these conditions that corrosion becomes very marked. A brass plate which had been immersed in sea water for several weeks, and which had corroded perfectly uniformly, was then so placed that $\frac{1}{4}$ inch of the plate stood above the surface of the liquid. In a few days the result was very noticeable; along and just above the junction of liquid and air pitting had occurred, and the metal became quite bright and crystalline in appearance. The direct effect of the reservoir would therefore be an increased rate of corrosion along a contour, which would narrow as evaporation progressed.

The second cause for pitting is the strong electro-chemical action set up by certain substances. Of these, ferric hydrate and carbon are probably the worst, and of the corrosion products of brass the oxychloride appears to be the most injurious. On two or three of the plates small pits were found under the patches of green deposit after the lapse of four months. The location of these patches depends on the roughness of surface. The causes of abnormally rapid corrosion must be due to the presence of stray currents of some magnitude. Corrosion may be accelerated by the interaction of the various products

of corrosion, but it is not rapid and local enough to give rise to pitting.

The Effect of Impurities in Brass.—To study the influence of lead, tin, aluminum and nickel on brass some alloys were prepared from the purest metals available.

The figures show that the initial effect of 1 per cent. and 2 per cent. lead, 1 per cent. tin and 2 per cent. tin, 1 per cent. aluminum and 2 per cent. aluminum, is to increase the resistance to corrosion, whilst that of the nickel alloys is to diminish it.

The Necessity of CO_2 and Oxygen for Corrosion.—In connection with the necessity of both CO_2 and O_2 for corrosion, a necessity which has been insisted upon by Professor Cohen and others, some experiments were carried out. 70/30 brass placed in a sealed flask of sea water, from which the dissolved gases had been removed by boiling, showed no signs whatever of corrosion after the lapse of several months. In the presence of oxygen only the surface of the metal became oxidized, and there was a slight loss of weight after four weeks, although the solution did not answer the ammonia color test for copper. The loss in weight may have been due to the removal of some non-adherent oxide when the specimen was being washed prior to weighing. The experiment is, unfortunately, inconclusive, but it seems difficult to understand why the presence of CO_2 should be essential. V. Andström, working on the rusting of iron, came to the conclusion that the proportion of O_2 and not that of CO_2 was the determining factor in the rate of corrosion.

Conclusion.—It is again urged that so important a subject as the corrosion of brass by sea water, the neglect of which must mean no slight expenditure, should induce steamship companies to keep records bearing on the subject. It has been this lack of data that has hitherto retarded the solution of the corrosion problem. All the companies with whom correspondence was opened possessed " no definite information."

The conclusions to be drawn from the paper are:

(1) That the presence of air or an increase of temperature up to a certain point accelerate corrosion.

(2) That iron, nickel and small amounts of lead are injurious; tin up to about 1 per cent., large amounts of lead, and aluminum are useful in diminishing corrosion.

(3) That the inlet pipe and the condenser plates should preferably be made of brass.

(4) That the condenser should be protected against stray currents.

(5) Protective coatings are not recommended.

(6) The importance of "spills" cannot be exaggerated.

(7) That the tubes should be flushed with clean water after use.—"The Engineer."

MARINE-JET PROPULSION.

By RANKIN KENNEDY. Paper read before the Manchester Association of Engineers.

This system of marine propulsion has some attractive features, especially in connection with the more recent prime movers, the internal-combustion engine, and the direct-acting gas pump brought out by Mr. Humphrey. The system of propulsion has hitherto, when put to practical test, been a sorry failure, but the failure was not due to any inherent defects in the system, but entirely to the use of very inefficient machinery and faulty design. The pump in marine jet propulsion is the propeller, so that if we start out to test the system with a pump the efficiency of which is known to be under 50 per cent., and on a design in which 50 per cent. of the engine power was expended in impressing the velocity of the vessel on the feed water to the pump, it is not surprising that the results were highly unsatisfactory. Low efficiency could have been predicted—in fact, it would have been surprising if the results had been otherwise than they were.

In this paper the endeavor has been to give an exposition of

the conditions under which marine-jet propulsion may be applied on correct principles efficiently, and with some assurance of obtaining the desired results or an approximation thereto. The direct action for ship propulsion of a pressure upon the water, generated by internal combustion, as in Humphrey's pump, dispensing as it does with all the intermediate mechanisms of pistons, cranks, shafts and screw propeller, is alluring, but as yet the problems in connection with its application are unsolved. In this paper the intention is to confine our considerations to the jet propeller only, and without reference to the prime mover. The essential points are the pump, its intake and discharge, and the quantity of water dealt with, also its velocities.

If a vessel containing water under pressure is mounted free to move on wheels, or on water, and a jet of water is allowed to flow, as in Fig. 1, the pressure P expelling the jet will also,

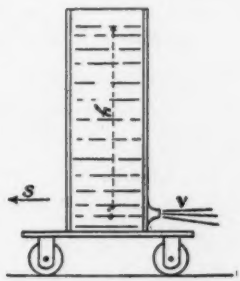

Fig. 1.—MARINE-JET PROPULSION.

by the law of action and reaction, propel the vessel in the opposite direction, and if P is the pressure in pounds per square inch, and A the area in section in square inches of the nozzle through which the jet is expelled, then the thrust or reaction T on the vessel is equal to—

$$T = 2\,P\,A \text{ in pounds} \ldots\ldots\ldots\ldots (1)$$

or if V is the velocity of the jet in feet per second, and W the weight of water discharged in pounds per second, then the thrust is equal to—

$$T = \frac{W V}{g} \quad \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

$g = 32.2$.

If A, the area of the jet, is given in square feet, then for sea water the weight of a cubic foot being 64 pounds—

$$W = A V \times 64 \quad \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

so that T may be found from—

$$\frac{(A V \times 64) V}{g} \quad \ldots\ldots\ldots\ldots\ldots\ldots (4)$$

Now, provided the pressure P is kept constant, T is constant, no matter what the speed of the vessel may be, or what the direction of its motion is, and T is also always equal to $\frac{W V}{g}$ irrespective of any motion of the vessel.

In jet propulsion the water is taken into the vessel through an orifice below the water line, at the speed S of the vessel, and increased in velocity by a pump (that is accelerated), and discharged astern from a nozzle. The thrust is due to the reaction of this acceleration. The water enters the vessel with a velocity S relative to the vessel; the pump gives it a further velocity U, so that it is discharged from the nozzle with a velocity relatively to the vessel equal to V.

$$V = S + U \quad \ldots\ldots\ldots\ldots\ldots\ldots (5)$$

But the velocity relative to the water outside the ship $= U$. U is therefore what we know in screw propulsion as real slip. The thrust therefore is equal to—

$$T = \frac{W U}{g}$$

or, when V is given—

$$T = W \frac{(V - S)}{g} \quad \ldots\ldots\ldots\ldots\ldots\ldots (6)$$

or

$$T = \frac{64\ A\ V\ (V - S)}{g} \quad \ldots\ldots\ldots\ldots (7)$$

This is all true provided the water enters the ship at the intake without check or hindrance, and at the speed of the vessel passes unchecked into the pump, is there accelerated, and then immediately expelled through the nozzle. It must not acquire the forward motion of the vessel. These are conditions difficult to realize except by the use of a screw as the pump impeller.

Referring to Fig. 2, showing a screw p in a funnel-shaped pipe—at the forward end it takes in water at the speed of the vessel S. If now the water is accelerated by the screw by a further velocity U, the column must contract as the speed increases until finally it has an area and corresponding velocity aft proportional to $S + U$, the area of the section of the column being inversely as the velocities S and $S + U$.

The thrust, of course, would in this case come on the screw, but if we put a bend on the aft end, as shown in dotted lines, the thrust of the jet would be at C, the thrust being always in opposition to the direction of the jet.

This jet propulsion, however, would be no improvement upon the screw outside the vessel; it would not be as good.

This method of working may be called the "velocity system," for the propulsion is entirely due to acceleration of water from the velocity of the ship to a higher velocity, and nowhere in its course is the velocity of flow checked in any way.

The only other type of pump capable of dealing with the quantities of water necessary, and maintaining an uninterrupted flow, is the centrifugal pump, and all practical attempts hitherto made at jet propulsion have employed that pump. Unfortunately, the centrifugal pump remained until quite re-

cently a very inefficient pump. In the case of the *Water Witch*, the first vessel tried, the pump efficiency was less than 50 per cent., and worse still in subsequent boats. So that to begin with it was useless to look for efficiency in the whole system. Pumps are now, however, better designed, and of efficiency over 80 per cent. In adopting jet propulsion it would be very likely necessary to design special pumps of very high efficiency, probably as high as 88 per cent. at full speed, and with sheet-steel casing, light in weight. At any rate, it would be folly to attempt jet propulsion with a pump under 80 per cent. efficiency.

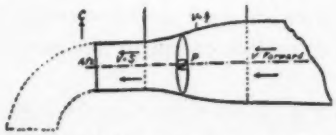

Fig. 2.—MARINE-JET PROPULSION.

Now about the slowest speed of a vessel on a voyage is equal to 16 feet per second (between 9 and 10 knots), and they run up to 34 knots or more—say about 50 feet per second.

These are the velocity limits between which the water would enter the ship's intake orifice.

We cannot here enter upon pump design and construction, but may point out that no centrifugal pump could deal efficiently with water entering even at the lower limit—16 feet per second, 10 feet per second, is about the highest permissible entering velocity, and that entails considerable losses. Five feet per second is often used. We cannot therefore work with a centrifugal pump on the "velocity system" with any efficiency. We must, of course, take the water into the vessel's intake at the velocity of the vessel, but that velocity must be reduced to something between 5 and 10 feet per second before it enters the pump eye.

This can be done without loss by a tapering intake tube (a "Venturi tube"), widening out as it approaches the pump. This is shown in Fig. 4.

Fig. 3 represents in diagram a pump for the velocity system, the water entering at the velocity of the vessel S, and being accelerated to $S + U$. But such a pump has not yet been invented to work efficiently.

In practice the pump is like the diagram Fig. 4. The water enters at the speed of the vessel, S, at D, but is reduced to say 7 feet per second in the expanding tube B, the velocity becoming pressure, as shown on gage 2, on the entering eye; the pump then *increases this pressure*, as shown on gage 1, and the water falls in pressure and increases in velocity in a converging nozzle C up to a velocity $U + S$ at the smaller nozzle end.

Fig. 3.—MARINE-JET PROPULSION.

This system may be called the " pressure system," the pump operating by raising the pressure instead of increasing the velocity. The increase of velocity takes place in the discharge nozzle only, and the losses in the pump are a minimum.

In the *Water Witch* trials by the naval authorities the entering water was arrested in a tank, and a large amount of energy wasted in impressing upon it the forward speed of the ship. If the water entering the vessel is arrested and compelled to move with the ship, the energy lost is proportional to $\frac{W S^2}{2 g}$, and might amount to half the total energy of the propelling power. This impressing of the vessel's velocity upon the incoming water must therefore be avoided in any scheme of jet propulsion.

In the gunboat afterwards tried the attempt was made to work the centrifugal on the velocity system, and, as was to be expected, both failed in efficiency, and jet propulsion was promptly condemned.

The efficiency of jet propulsion is like that of the screw, dependent upon the slip; but with the jet the slip may be large. If the slip is small a great mass of water is required, entailing large pumps, so that on the whole question it has been found that when $2 \times S = V =$ the discharge velocity of the jet, we have a good proportion. This gives $S = U$.

The efficiency is then—

$$\frac{S}{S + \frac{U}{2}} \quad \ldots\ldots\ldots \quad (8)$$

If $S = 16$ feet per second, V in this case would be also 16 feet per second, and the efficiency η.

$$\eta = \frac{16}{16 + \frac{16}{2}} = 0.66;$$

that is, about the same as a good screw propeller. A smaller slip may be allowed on higher-speed vessels with consequent higher efficiency.

It has been imagined that the dimensions of the orifices in the jet-propelled vessel would be nearly that of the gigantic disc area of a screw propeller. But this is far from being the case.

A ten-knot tramp steamer with 1,000 H.P. would have a midship section of about 800 square feet, and a screw of about 16 feet diameter, of 200 square feet area, or one-quarter of the ship's midship section.

I shall presently show that two jets of 35 inches each in diameter would give the same thrust with the same power as the 16-foot propeller. In higher-speed vessels the orifices or jets are smaller in proportion to the horsepower, and jet propulsion is rather more favorable to higher-speed vessels.

The actual work done in ship propulsion by any propeller is equal to T, the thrust, multiplied by the speed of vessel S.

$$\text{Work} = T \times S \ldots\ldots\ldots\ldots\ldots (9)$$

η, the total propulsive efficiency, is equal to—

$$\eta = \frac{T \times S}{\text{I.H.P.}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (10)$$

This in present-day ships may be taken as equal to 0.5, although it may reach 0.6 in some cases.

If we take this tramp steamer at 17 feet per second $= S$, we can find the thrust she requires, and from that we can proceed to calculate the principal dimensions of the jet system.

$$T = \frac{550 \times \text{I.H.P.} \times}{S} \quad \ldots\ldots\ldots\ldots (11)$$

Then in this case—

$$T = \frac{550 \times 1000 \times 0{\cdot}5}{17} = 16{,}000 \text{ pounds.}$$

If the slip is equal to the speed of the ship, then the quantity of water per second would be thus found.

Thrust per pound of water $= T = \frac{U}{g}$ and so

$$Q = \frac{g \times T}{U \times 64} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (12)$$

64 being the weight of 1 cubic foot, and the volume or cubic feet Q per second $=$

$$Q = \frac{32 \times 16{,}000}{17 \times 64} = 470 \text{ cubic feet.}$$

A_1, the area of the intake required to take this quantity in at 17 feet per second, $= A_1 = \frac{470}{17} = 27$ square feet, and as the jet has twice the speed of the ship the area of the jet nozzle would be half that. But we would have at least two pumps, with four inlets and two jets, so that we would have $\frac{27}{4} =$ 6.75 square feet for each inlet, and the same for the two nozzles equals about 35 inches diameter each.

In the above formulæ for Q and A_1 it will be noticed that A_1 is equal to the thrust T divided by twice the square of S, the vessel's speed, hence A_1, the area of the inlet in square feet, can always be found in any case by—

$$A_1 = \frac{T}{S^2 \times 2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (13)$$

and A area of jet $= \frac{A_1}{2}$ when the speed of jet relative to ship is twice the speed of the ship.

If the speed at intake is 17 feet per second, we must reduce this at the pump eye by at least one-half, say to 8.5 feet per second, so that the pump eyes will require to be each $2 \times 6.75 = 13.5$ square feet, or about 4.2 feet diameter.

This large diameter would limit the revolutions of the pump to a very small number, and thus entail a large slow-speed engine. Therefore, it is better to use centrifugals with multiple impellers delivering in parallel, thus increasing the number of inlet pump eyes, and the diameter of the impellers would thus be reduced. And there might be two engines, each with two pumps, and each pump with two impellers, giving eight inlet pump eyes, thus bringing down the diameter of each eye to 3 feet. This could be carried still further by pumps having four or six impellers in parallel, so as to obtain higher speeds of pump wheels. Higher-speed vessels are more favorable towards jet propulsion, for less water per horse-power has to be dealt with. In the slow-speed vessel a large quantity has to be raised to a low head; in the high speeds we have a less quantity at a higher head, higher pump speeds, and higher engine speeds.

One of the difficulties with jet propulsion is due to the large weight of water necessarily carried on board the ship, especially when the full speed S is low. If an example is calculated out for a higher-speeded vessel, say about 24 knots, this will be seen. In most cases the marine engineer is given the thrust required to propel the vessel in which the marine

propeller is to be installed, and also the speed required of the vessel at its maximum is given.

The dimensions of the jet propeller are then easily calculated from these two values.

Suppose T, the thrust required, is given as 32,000 pounds, and speed in feet per second $= S = 40$ feet per second. If we decide to make the jet velocity V twice the velocity of the ship, the jet velocity would be 80 feet per second—a velocity which would enable us to use high-speed pumps if the impellers were in parallel delivery.

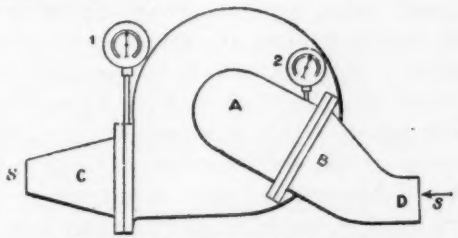

Fig. 4.—Marine-Jet Propulsion.

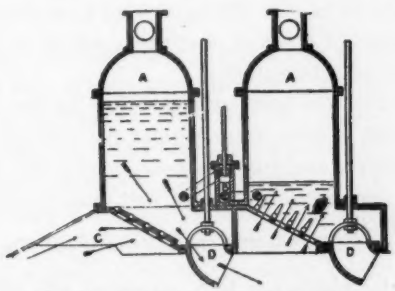

Fig. 5.—Marine-Jet Propulsion.

By (12) the quantity of water would be in cubic feet—

$$Q = \frac{g \times T}{S \times 64} = \frac{32 \times 32{,}000}{40 \times 64} = 400 \text{ cubic feet per second.}$$

By (13) the total area of intakes would be—

$$\frac{32{,}000}{40 \times 40 \times 2} = 10 \text{ square feet.}$$

Hence, if we had four inlets they would each be only 2.5 square feet area, equal to 21.5 inches diameter, with two jets of same diameter.

But the pump eyes would require to be much greater in diameter. If we decided to make the inlet velocity at the pump eye = 10 feet per second (that is, a fourth of the vessel's speed), then the area of the pump eyes would be $4 \times 2.5 = 10$ square feet each, or 3.5 feet diameter nearly.

If pumps were desired to run at a higher number of revolutions, the only plan would be to have more wheels in parallel, with, say, eight inlets or more. These calculations throw a considerable amount of light on jet propulsion when the centrifugal pump is the impeller. It is essentially a pressure pump, in which the velocity of the fluid is low, whatever the head may be against which it is pumped; this fact compels the use of large pumps, and the carriage of a large volume of water on board the vessel in transit from intake to nozzle.

If a pump could be devised to take the water in at the ship's velocity, then double its velocity, and then expel it, such a pump in the above case would have inlet eyes only 21.5 inches diameter, instead of 3.5 feet, and the quantity of water in the ship comparatively insignificant.

The gas pump has been proposed for the purpose, but all the propositions I have seen neglect the fact that they will take in the water, and impress upon it the full forward velocity of the ship from a state of rest, and so lose energy at the rate of $\frac{S^2 W}{g}$. By some means the incoming water's velocity might be converted into pressure, and thus save the energy. But hitherto no one has shown how this is to be done in practice, except in the case of the centrifugal with an expanding inlet tube. As an example I may take one case: P. F. Macallum, Glasgow, in Patent 13,517 of 1886, describes a gas pump for marine-jet propulsion, which, I am informed, works fairly well in a small scale. It is shown in diagram, Fig. 5, and described as follows:

"The feed intake *C* faced forward, and when the vessel

was in motion the water passed in a fairly constant stream to one or other of the two large cylinders *A*, *A*. The momentum of the feed in the cylinder which was being filled was utilized in compressing a volume of air into which, at about the instant of greatest compression, a charge of liquid or solid pulverized fuel was injected and ignited. The resultant combustion and expansion drove the water out through the nozzle *D* while the other cylinder was being filled, and so on. The removal of the combustion products was facilitated by a scavenging charge of air or by a steam jet. The nozzles *D*, *D* might be operated from the deck, and turned in any desired direction. The small hydraulic engine *P* received a reciprocating motion from the explosions in the large cylinders, and might be used to drive a fan or air pump. The apparatus was only tried on a very small scale, but the action was obviously of the most direct kind possible."

In this and some other propositions the only compression possible is that due to the velocity of the incoming water being arrested in the cylinder, the head being equal to $\frac{S^2}{2g}$, S being ship's speed. In high-speed vessels this would be considerable, but in slow speeds not much; even in the case of a vessel with 40 feet per second speed, or 24 knots, the compression could not exceed 10 pounds per square inch, or thereabout.

This design is faulty, for in order to get efficient intake and all the compression possible, the water should enter by an expanding conical tube, and so gradually come to rest. Rushing through a grid of valves the water would strike the aft sides of the cylinder, and the velocity would be destroyed by turbulence, with consequent resistance to propulsion.

The Humphrey pump, of course, obtains compression independent of the ship's speed. In the paper read on the subject of this pump by Mr. Humphrey, 12th November, 1910, before this Association, a diagram is shown of a proposed outfit for propulsion by this pump, but from the diagram it is not very clear how the intake is managed. Taking water in at the sides of a vessel is faulty, and long pipes with air vessels for

the same reason are objectionable, for when the vessel rolls and pitches the intakes at the side are alternately immersed deeply and then uncovered, and the water oscillates about in the pipes when the ship rolls.

Properly, the intakes should be in the bottom of the ship, and through scoops facing forward. Far more attention has to be paid to the intake of the water than to the jets. The jets may be at the sides of the ship or astern. And it makes no difference whether they are immersed or not so far as propulsive effect is concerned; hence a jet propeller is better in a rough sea, or on a vessel in light trim, than a screw propeller.

The application of an intermittently acting pump presents several problems not yet overcome, one of which is, that if the intake of water is continuous, as it should be, storage will have to be provided between strokes, thus adding to an already large volume of water on board.

And this quantity might seriously add to the vessel's displacement, thus reducing cargo-carrying capacity. There can be no doubt, however, that if the direct-acting gas pump can be used for jet propulsion the combination would be the best system known.

The possibilities of jet propulsion need not here be gone into, but it may be remarked that the vessels which have hitherto been tried in actual practice were foredoomed to failure, for they either started out with a pump of low efficiency, and but poorly calculated for the purpose, or the whole system was designed so that a great amount of the energy of the engines was destroyed before it came to do the useful work of expelling the jet. And no correctly designed experiments have yet been made with jet propulsion employing modern machinery on a scientific scheme.

For some purposes the jet-propelled vessel would have advantages, whatever the prime mover it may employ. It would be a very interesting experiment to try a vessel at fairly high speeds with high-speed modern engines and pumps, all prop-

erly designed and fitted up for the best results. This has never been done.

Finally, it may be useful in discussing the subject to classify the systems of jet propulsion. From this paper it may be gathered there are three systems:

1st. That in which the water is taken into the vessel, and the velocity of the vessel impressed upon it by an expenditure of energy, which is lost, and then has a velocity impressed upon it by a pump discharging it through a jet, the reaction propelling the ship.

2d. That in which the water is taken into the pump at the velocity of the ship, is accelerated by the pump and discharged through a jet, the reaction propelling the ship.

3d. That in which the water enters the vessel at the velocity of the vessel, and this velocity is reduced to a value between 5 and 10 feet per second in a Venturi expanding tube before it enters the pump, the velocity being converted into pressure. The pump then increases the pressure on the water, which in discharging through a converging nozzle acquires a velocity the reaction of which propels the vessel.

The first system has been proved a failure by direct tests. The energy lost in impressing the velocity of the ship upon the incoming water reduced it to hopeless inefficiency, and the pump used had an efficiency of about 48 per cent. only.

The second system has also been tried and proved a failure, but from different causes. The failure was here due to the great losses in the centrifugal pump taking the water in at the speed of the ship = 30 to 40 feet per second—and the pump itself being inefficient.

The third system, which is really the only truly scientific one, has not been tried on a large scale, but as it steers clear of the obviously inefficient practices of the other two, and may be worked with a highly efficient pump, it may be reasonably expected that jet propulsion on this system would show really what it could do in comparison with other systems of propulsion.

JET PROPULSION.

It is probable that there are many engineers who would be somewhat startled by the assertion that jet propulsion is the most efficient method yet devised of propelling any type of vessel; and yet, if attention is directed solely to the jet itself, the statement is strictly and indisputably true. If, for instance, a vessel could, whilst standing still, pump into large air vessels enough water to carry her through to her destination, propulsive efficiencies of the order of 80 per cent. or more would be readily realizable. The whole trouble arises from the fact that the boat must pick up water as she moves. The drawbacks to this are both theoretical and practical. Thus theory shows that in the case of a tank propelled by the reaction of a jet issuing from an orifice at its rear, the efficiency of the jet would be unity when the speed of motion was half the speed of flow. If, however, the tank has to pick up its water as it goes, the efficiency will, at most, be only two-thirds when the traveling speed is half the speed of issue. The latter is, no doubt, a reasonably high value, considerably in excess of that of the ordinary screw propeller, but in the case of the latter the efficiency is an over-all one, whilst in the case of the jet, to its own losses must be added those involved in the means employed to capture the water, increase its velocity or pressure by pumps, and to deliver it finally to the jet. These losses have commonly been very large, and there seems little prospect of any serious improvement being effected. In fact, the difficulty in some respects resembles that which arises in coupling a steam turbine to a screw propeller. To be efficient the power-generating machine should handle a small quantity of water at a very high pressure, which means a high velocity of discharge. This was realized some twenty years or so ago by an American inventor, who installed, on a launch, pumping machinery designed to produce a jet to be delivered under a head of over 3,000 feet. This portion of his plant was no doubt extremely efficient, and its designer had the most sanguine expectations as to effecting a revolution in

methods of ship propulsion. Being, moreover, unacquainted with mathematical principles, demonstrations thereby of the utter futility of his ideas failed to discourage him, and the experiment was accordingly tried on a very liberal scale. The result, of course, was a foregone conclusion, the efficiency of his pumping plant being wholly obliterated by the pitiful inefficiency of the jet produced. What is needed to solve the problem of jet propulsion is some means of handling the water on board ship in small volume, and at a correspondingly high pressure, and of then transferring the energy of this mass to a larger body of water, which should form the actual jet. An obvious proposal is to use something of the nature of an ejector, but it is easy to show that in this case the thrust of the large mass sent astern is at the best no greater than that of the original high-velocity jet, so that the arrangement is in actual fact considerably worse than would be the direct application of the latter. Another suggestion, plausible at first sight, is to pump the water at a high velocity, and hence through pipes of moderate diameter, and then discharge it astern through a divergent nozzle, thus getting the desiderated low velocity of discharge. The trouble with this plan lies in the fact that the pressure of the jet at the discharge end of the nozzle must be that of the atmosphere (assuming the discharge takes place above water level), and therefore the pressure at the throat must be less than this. What is required to secure compact pumping machinery is, on the contrary, a high water pressure, since the energy is proportional to the product of the pressure and the volume, and it is the latter which is the governing factor in the cost and weight of the machinery employed.

We are not therefore sanguine that it will prove feasible to apply successfully any known form of pump to ship propulsion on the water-jet system. Should, therefore, the Humphrey internal-combustion pump prove as economical for large outputs as it has already done in the smaller sizes, it seems probable that any attempt to adapt it to ship propulsion will take the form of using the discharge from the pump to drive a

turbine, and let the latter drive an old-fashioned screw. The advantage of such a method lies in the fact that the volume of water on board, at any time, might be very moderate in quantity. The losses in getting it on board, which are a large proportion of the head corresponding to the ship's speed, are thus minimized, and a compact and relatively efficient plant should result.

It may be objected that this system is complicated, but occasionally the "longest way round" is really the "shortest cut." An internal-combustion pump will not be applied to marine propulsion unless its own efficiency is so high that a substantial saving of coal can be effected. The problem to be solved is, in fact, twofold. In the first place, it is necessary to have an efficient means of producing power, and, in the second, an efficient method of utilizing it. With jet propulsion pure and simple the two elements of the problem make incompatible claims. Owing to considerations of cost and weight, an efficient pump means in practice an inefficient jet and *vice versa*. If, however, a high-pressure Humphrey pump can be designed which will yield 1 horsepower at, say, 25 per cent. less fuel cost than a good marine engine requires to develop 1 shaft horsepower, the combination of turbine and screw becomes a commercial proposition, and the plan of effecting the ultimate propulsion by a jet can be dismissed.

In a paper read on the 13th of October before the Manchester Association of Engineers, Mr. Rankin Kennedy advocates another solution of the problem. His proposal is to use centrifugal pumps of a modern design, for which he anticipates over 80 per cent. efficiency. We do not know of any low-lift centrifugal pump with such an efficiency as this, and a low-lift pump would be required in practice. Possibly 75 per cent. might be reached with very careful design, but it would mean an enormous pump with large diffusion chambers. Mr. Kennedy suggests that a centrifugal pump is "essentially a pressure pump, in which the velocity of the fluid is low, whatever the head pumped against." This statement, we think, is calculated to convey a wrong impression, since, as Rankine

pointed out years ago, half the energy of the fluid in a forced vortex is pressure energy, and the other half kinetic, so that the velocity is 7/10ths of that due to the maximum head.

If the water taken into the vessel is brought to rest relatively to the vessel, a velocity head equal to $\frac{s^2}{2g}$ (s being the speed of the vessel in feet per second) must either be destroyed or converted into pressure head. This conversion Mr. Kennedy proposes to effect by letting the water enter the centrifugal through a divergent nozzle. The latter is, however, likely to prove a very inefficient device. Unless the taper is kept below about 1 in 10, the losses become enormous, and we hope shortly to publish a description of a very important and careful series of experiments, by Professor Gibson, which showed that unless this limit was adhered to, the loss was actually greater than when the whole of the reduction of velocity was effected by a sudden enlargement of the pipe.

There remains one other possible plan of operation—viz: not to bring the water to rest in the vessel, but to let it enter the impeller of the pump with its initial relative velocity. This, Mr. Rankin Kennedy claims, is an inefficient method of operation, and this is, perhaps, true. The method, however, is exactly that on which the ordinary screw propeller operates. The latter, it is known, has no appreciable centrifugal action. It takes in the water (apart from the wake correction) at the speed of the ship, accelerates it, and discharges it astern; working very much in the same way as if completely cased in.—"Engineering."

ELECTRIC DRIVES FOR SCREW PROPELLERS.

By H. A. Mavor. A paper read before the Engineering Section of the British Association for the Advancement of Science, England, September 1, 1911.

The problems of marine engineering have until recent years been solved exclusively by the application of various forms of reciprocating steam engines, and the power, speed, form and

general arrangement of power-driven vessels have been developed in connection with this means of propulsion. The advent of other appliances has opened up new lines of development, and in certain departments there is evidence of need for intermediate devices between the power-producing and the power-absorbing elements.

The necessity for these devices arises when the properties of the propeller in respect of rate of revolution are incompatible with those of the power generator. This incompatibility is most conspicuous in vessels which have to operate at relatively slow speeds. An examination of the conditions which have emerged in the development of marine propulsion soon shows that the incompatibility is not accidental, or due to imperfections in the design, construction, or use of the propelling equipment, but that it is associated with the essential properties of the substances and appliances with which we have to deal.

It may be said in general terms that high efficiency is associated with low rate of revolution of the propeller, while in the steam turbine high rates of revolution are essential to the most economical use of the steam. Internal-combustion engines have speeds more nearly approximating those of reciprocating steam engines, but here also there is a tendency to speeds higher than are convenient or economical from the propeller standpoint.

In addition to those fundamental incompatibilities arising from causes out of the reach of direct accommodation, there are other conditions which limit the direct application of engine to propeller. The draught, beam and form of the vessel limit the area of the propeller. The traffic for which the vessel is designed influences the determination whether one, two or more propellers are to be used, and the speed, size and form of the vessel determine limits to the designer's choice. All these considerations taken together frequently fix the diameter, pitch and thrust of the propeller within narrow limits and also the rate of revolution. Now this rate of revolution is not al-

ways the most favorable for the power generator, and the designer is in such cases compelled to resort to new expedients if he is to attain the standard of efficiency in power generation which has been set by the results attained on land. At the present moment the economy of power production in the best practice on land is considerably in advance of what has been done at sea. The principal reason of the better economy of the land work is the higher rate of revolution of the power generator when untrammelled by propeller conditions.

There are cases where the special limitations in respect of dimensions and weights permissible for the machinery are such as to preclude the use of any intermediate mechanism between the prime mover and the propeller. In a ship whose voyage is short, whose speed is high, displacement small, and the propeller efficiency as good as is attainable, and the quantity of fuel carried small relative to the weight of machinery, the possible economy in fuel may be insufficient to warrant any increase in the weight of machinery; or, to put the case otherwise, it is advisable to sacrifice economy in fuel to keep down the weight of the equipment—*e. g.*, a vessel running one-day voyages, and burning 50 tons of coal, could not possibly submit to an increase in weight of machinery in excess of the coal saving, because such increase would increase the displacement and the power necessary to drive the vessel. If, on the other hand, the vessel makes a ten-day voyage, and the saving in fuel carried amounts to ten tons per day, a considerable increase in weight of machinery might be associated with decreased displacement and a substantial all-around economy.

Various methods of making the required adaptation of generator to propeller are at present under trial. Mechanical gearing by toothed wheels and hydraulic transmission may be considered serious competitors of electric transmission but for large powers it seems reasonable to expect that electric transmission, which is already developed for this very purpose on land, is likely to find an equally useful field where the

conditions are such as to require an intermediate device at sea.

The cost, weight and efficiency of electric transmission compare favorably in the examples which have been examined with either of the two competing methods. There are other important qualifications of electric transmission in which it stands altogether unrivalled. It provides a ready means of reversing the direction of rotation of the propeller without changing the direction of rotation of the power generator. The electric transmission also provides means for changing the speed ratio between generator and propeller, so as to permit of the power of the generator being developed under the most favorable conditions at all speeds of the ship. Lastly, it provides means for applying the power of one or more engines to one or more propellers, so that the power-generating units may be so disposed as to give the highest efficiency, and when they are not required they can be stopped.

These properties of the electric transmission supply exactly what is required to render steam turbines, and also internal-combustion engines, completely adaptable to the purpose required. Both types of power generators give their best efficiency when full speed of rotation is maintained, even when running below full power. It is, therefore, advantageous to keep the engine revolutions within the range of governor control, while the required speed change is accomplished by electric combinations.

The properties of the electric motor lend themselves well to the requirements of maneuvering. The rate of reversal is under perfect control. The possibilities of rapid and certain action are more than are attainable in a reciprocating steam engine connected direct to the propeller, and the electric motor is applicable to powers for which there is no possibility of using anything in the nature of reversing gears or clutches.

The property of combining the power of more than one engine for application to one or more propellers is the special feature of the author's invention as distinguished from the ordinary methods of electrical engineering. Engines of dif-

ferent types, sizes and rates of revolution can have their powers combined without interconnection of their electric circuits, and without risk of mistake or error. An oil engine at 100 r.p.m. may be running the vessel at slow speed, and a steam turbine running at twenty times the speed may be jointly applied to the propellers without any complication of the electric equipment. Each unit does its own work independently.

The advantage of such an equipment in vessels which are required to operate under varying load conditions is evident. Without subdivision of the power units, the whole of the main machinery must be in motion while the ship is in motion. At speeds reduced below its normal rate of revolution the steam turbine is less economical than the steam engine. Subdivision into high-pressure, low-pressure and intermediate elements has been carried out, in certain steam equipments, but this results in a somewhat complicated and inconvenient system of piping, because the steam has to be led from one part of the system to the other across the vessel. In the electric system each unit can be self-contained, and disposed in the manner best suited to a convenient arrangement of the engine room. The size of the individual units can be adjusted to suit the powers required at the different working speeds, or they may be duplicate.

Turbo-Electric Steamship Frieda.—This vessel has been specially designed for the transport of bulk freights between the Gulf of Mexico and New York City. The vessel is to be 300 feet long, and will carry a dead weight of approximately 5,000 tons, at a mean loaded speed of 12 knots at sea. The propelling machinery is aft, and consists of a turbo-electric outfit for 1,500-kw., three-phase, 50 cycles when running at 3,000 r.p.m. The turbine is supplied with steam at a pressure of 200 pounds per square inch at the turbine stop valve. This electric generating plant is arranged on foundations on a platform deck in the engine-room hold. The condenser is fitted with a vacuum augmenter, and is suitable for dealing with the full-load quantity of steam from the turbine. The vacuum

obtained will be 28½ inches, with cooling water about 85 degrees F. This condensing plant consists of a vacuum condenser, three-throw air pumps and centrifugal circulating pump with electric-motor drives. The current is led to a three-phase motor, which is keyed direct to the main propeller shaft, and is capable of developing 1,900 B.H.P. at a speed of about 84 r.p.m. The steam is generated in two Scotch boilers, with Howden's forced draft, and liquid-fuel burners. This installation costs and weighs less than the normal equipment. The coal saving is over ten tons per day. The design of the ship itself presents many other novel features. This design was prepared by Messrs. John Reid & Co., 17 Battery Place, New York City.

THE PROGRESS OF THE PARSONS MARINE TURBINE.

Some interesting particulars as to the progress of the Parsons marine steam turbine are given in the annual report of the Parsons Marine Steam Turbine Company, Limited, as submitted to the fourteenth annual general meeting of the shareholders on October 18. At the Turbina Works, there are in progress the turbine-propelling apparatus for H.M. battleship *King George V*, building at H.M. Dockyard, Portsmouth; for H.M. unarmored cruiser *Amphion*, building at H.M. Dockyard, Pembroke; three sets of turbine machinery for three torpedo-boat destroyers, recently ordered for H.M. Navy, from the London and Glasgow Engineering and Iron Ship-Building Company, Limited; two sets of geared turbine machinery for two passenger vessels, ordered from the Fairfield Shipbuilding and Engineering Company, Limited, by the London and South-Western Railway Company; two low-pressure turbines of the "combination" system, to be fitted in a steamship which is building for the Cia. Trasatlantica (Spanish), at the Neptune Shipbuilding Yard of Messrs. Swan, Hunter & Wigham Richardson, Limited.

The extent to which the Parsons type of turbine continues to be employed in the warships of the world is indicated by the following brief summary:

France.—Six battleships of the *Danton* class, fitted with Parsons turbines, have been completed, having passed through their contract steam trials with entire success. Parsons turbines for two larger battleships, which have been launched recently, have been far advanced in construction, and will soon be placed on board these vessels. Contracts have been made also for turbine machinery for two other battleships. Two destroyers, the *Casque* and *Bouclier,* fitted with Parsons turbines, have been completed, and have attained very high speeds on their trials. Three other destroyers now in hand are to have Parsons turbines.

Germany.—The armored cruiser *Moltke,* fitted with Parsons turbines, has been completed. On her preliminary trials she exceeded in speed all her predecessors. The small protected cruiser *Augburg* has proved most successful. Parsons turbines are also fitted, or are ordered, for three battleships, two large unarmored cruisers, two small cruisers, and six destroyers. The total horsepower of Parsons marine turbines ordered for German warships of the present year's naval program will exceed 280,000 shaft horsepower, which represents 58 per cent. of the total horsepower to be ordered for German warships during the present financial year.

United States.—The battleship *Utah,* fitted with Parsons turbines, has completed her contract trials, and has exceeded her guaranteed speed by half a knot. Three other battleships and seven destroyers, now building, will have Parsons turbines.

Austria.—The turbines have been completed for the first battleship now building. Those for the second ship have been nearly completed; and during this year Parsons turbines have been ordered for the third ship, as well as for twelve large torpedo boats.

Russia.—One battleship and four destroyers, all with Parsons turbines, have been ordered for the Black Sea fleet during

the year, and negotiations are proceeding for two more battleships and four destroyers. Three battleships previously ordered have turbines of the same type.

Spain.—Work on the battleships now in process of construction with Parsons turbines has been considerably advanced. The turbines for two torpedo boats have already been completed and tried with entire satisfaction.

Japan.—Parsons turbines have been ordered for the large armored cruiser now building by Messrs. Vickers, and for three sister ships to be built in Japan.

Turkey.—A contract for a battleship with Parsons turbines has been placed in this country, and a second battleship will shortly be placed.

In ships of the mercantile marine the use of Parsons turbines is steadily advancing. The new Cunard steamship *Aquitania,* building by John Brown & Co., and the two new Hamburg-America steamships now building at Hamburg—three steamships which will exceed in size ships now afloat or building—are all to be propelled by Parsons turbines. The new high-speed French trans-Atlantic steamer *La France,* which is to be completed early next year, will be similarly propelled. The Canadian Pacific Railway Company have ordered from the Fairfield Shipbuilding and Engineering Company, Limited, two turbine-engined steamships for their Pacific service. Amongst swift cross-Channel and coasting steamers the *Newhaven* (built in France) may be mentioned; she has maintained a mean speed on service of nearly 24 knots. For the South-Eastern and Chatham Railway Company's cross-Channel service, Messrs. Denny have recently delivered the new turbine steamer *Riviera,* and a second vessel, the *Engadine,* has just been launched from their yard. The three Belgian cross-Channel boats now in service are giving most satisfactory results, both as to speed and economy, and in consequence Messrs. John Cockerill & Co. have received the order for two more boats embodying all the most recent improvements. In Japan the Mitsu Bishi Company (licensees of the company) have recent-

ly received an order for a vessel to be fitted with geared turbines, and inquiries for British ships are now being dealt with. The "combination" system, in which Parsons low-pressure turbines are associated with reciprocating engines, continues to gain ground, and the working of vessels of moderate speed so propelled has proved very satisfactory. It is reported that during the earlier voyages of the *Olympic* the working of the propelling machinery has fully realized the anticipations of the builders. Messrs. Harland & Wolff are now constructing for the Royal Mail Steam Packet Company the large steamer *Arlanza,* in which the combination system is to be used. Up to the present time the total horsepower of marine turbines of the Parsons type completed and under construction in the works of the company and of licensees, as well as in the works of the Continental sub-companies, and of licensees of Parsons Foreign Patents Company, Limited, amounts to about 6,400,000 horsepower—an increase during the year of about 1,900,000 horsepower. Of this total horsepower, nearly 5,300,000 horsepower are, or will be, employed for the propulsion of warships, and over 1,100,000 horsepower in vessels of the mercantile marine and yachts. At present the total number of vessels built and building for the Royal Navy and the Colonies with Parsons turbines is 167; the total horsepower is about 2,740,000.

From the commencement of the work of the company it has been recognized that great importance must attach to experimental investigation of the numerous and difficult problems which influence the efficiency of marine steam turbines and screw propellers, and considerable expenditure has been incurred in carrying out such investigations. It will be noted from the accounts that the directors propose to continue to work on the same lines, and they are confident that the provision made for experimental work this year (5,600*l.*) will prove reproductive, as it has done in the past. The profits for the year, after providing for depreciation on buildings, plant, machinery and office furniture, upkeep of patents, etc., trans-

ferring 5,600*l.* 13s. 8d. to the experimental work account, 5,000*l.* in reduction of patent rights account, and writing the company's holding in Consols down to 78*l* per cent., amount to 26,370*l.* 16s. 11d. The amount brought forward from the last balance sheet is 17,548*l.* 2s. 8d. The total amount available for distribution is thus 43,918*l.* 19s. 7d. This the directors recommend should be appropriated as follows: A dividend of 10 per cent., with a bonus of 5 per cent., is proposed, leaving 17,508*l.* 19s. 7d. to be carried forward.—"The Engineer."

THE MARINE OIL-ENGINE.

The application of the internal-combustion engine for the propulsion of ships is making progress, steady, if slow, and it is noted in the annual report of Lloyd's Register that there are now being built twelve merchant ships fitted with oil engines. The largest for registry with this society is to be of 8,000 tons gross, and five others are to be of 4,500 tons gross register and upwards, so that in a year or so much important data will be available regarding the reliability and economy of such engines in long over-sea voyages. It should be added also that several vessels are being built under the supervision of other registry societies. So far two oil-engine-propelled ships have made over-sea voyages—the *Toiler* to Canada and the *Vulcanus* from Rotterdam to the Black Sea and back, and promising results have been got. As to the design of engines there is wide divergence, although practically all are on the Diesel principle. A double-acting two-stroke-cycle engine for one of the largest ships referred to has been erected, and is undergoing shop trials before being fitted on board; but most of the other engines are of the single-acting type, adapted for the two or the four-stroke cycle. The double-acting engine has attractions; but it remains to be seen how the difficulties, notably of the stuffing box, are overcome. Certainly many shipowners, and still more marine-

engine constructing firms, are watching developments, ready to take definite action provided encouragement is afforded by the results. It is gratifying also to find that Lloyd's and other registry societies are alive to the importance of the subject, and distinctly sympathetic in their attitude.—" Engineering."

OIL FUEL FOR STEAM BOILERS—THE ECONOMICS AND TECHNOLOGY OF OIL-FIRED STEAM PLANTS, WITH SPECIAL REFERENCE TO ATLANTIC COAST CONDITIONS.

B. R. T. Collins, American Society of Mechanical Engineers.

Cheap water transportation from Gulf ports and keen competition among dealers have reduced the price of fuel oil in the Atlantic Coast States to a point below that at which it can be purchased in western Texas. The production of crude petroleum is continually increasing, and the supply of residual fuel oil released by the enormous demand for gasolene shows a corresponding growth. With the opening of the Panama Canal cheap transportation will be provided for California's surplus production and for the petroleum of Mexico, Ecuador, Peru and Chili. Attention is being turned to the possibilities of oil fuel for steam raising by the gradually increasing cost of steam coal on the Atlantic Coast, and particularly in New England; a paper by B. R. T. Collins, read last April before the American Society of Mechanical Engineers, shows that there already exists in New England a comparatively small but gradually increasing field for the use of oil fuel for steam generation in plants where special conditions enable a net saving to be made when everything entering into the problem is taken into consideration.

Fuel oil, the residual product of the removal from crude oil of water and the lighter hydrocarbons, like naphtha and gasolene, is more satisfactory for burning purposes than crude petroleum. The latter can be burned safely when proper pre-

cautions are taken; the advantage of fuel oil lies in the fact that in addition to having a higher flash point and calorific value, it can be used for fuel by men of ordinary intelligence with practically the same safety as coal.

The present supply of fuel oil, of course, can take care of only a small proportion of existing steam plants now using coal, but it is reasonable to expect that the increasing production of petroleum will release fuel oil in sufficient quantities to supply a gradually increasing number of plants in which fuel oil can be economically substituted for coal. The classes of plants in which profitable substitution is possible comprise:

First. Those in which the cost of handling coal by ordinary methods is higher than the average because of local conditions, and where the installation of suitable coal-handling equipment would not be warranted by the saving effected.

Second. Plants where boilers are fired by hand and more than one fireman is required on each shift. One man, for example, can take care of a battery of four 500-horsepower oil-fired boilers requiring four firemen and possibly a water tender and coal passer on full-load shifts with operation on coal.

Third. Plants where greater capacity is required than can be obtained with the coal available. The substitution of fuel oil for even high-grade coal will increase plant capacity at least 35 per cent.

Fourth. Plants where the boiler capacity is limited by the capacity of the existing stack or stacks, and where it is not desired to instal stack capacity, although more boiler capacity must be obtained. For the same boiler capacity oil fuel requires only about 60 per cent. of the stack area required for coal.

Fifth. Plants where absolutely smokeless combustion is demanded by the nature of the manufacturing processes.

Sixth. Plants where it is necessary to keep smoke below a certain fixed limit at all times, to comply with smoke ordinances.

The advantages of oil fuel may be summarized as follows:

a. The 30 per cent. higher calorific value per unit of weight than high-grade coal.

b. Smaller storage requirements, oil fuel having 50 per cent. higher calorific value than an equal volume of coal.

c. No deterioration in storage.

d. Lower temperature in boiler.

e. Smaller stack requirements.

f. Decreased loss of heat up the stack, due to cleaner tubes and the smaller amount of air which has to pass through the furnace for a given calorific capacity of fuel.

g. Higher efficiency, due to more perfect combustion with less excess air, more equal distribution of heat in combustion chamber, and the small amount of soot deposited in the tubes.

h. Increase in capacity of 35 to 50 per cent.

i. Even distribution of heat over the entire heating surface of the boiler, with less destructive influence on the metal surfaces.

j. Ease with which fire can be regulated, extinguished in any emergency, and relighted. In less than half an hour a boiler can be brought up to 150 pounds steam pressure from cold water. With automatic regulation the steam pressure can be maintained within 5 pounds total variation, with sudden changes in load amounting to 50 per cent. and over.

k. Smoke can be entirely eliminated.

l. No cleaning of fires.

m. Much lower cost for handling fuel.

n. Absence of coal dust and ashes and less wear and tear on pumps and other machinery.

o. No damage to furnace from firing tools, and no removal of clinker from furnace.

p. Less loss of fuel in handling.

q. Great saving in all kinds of labor.

The disadvantages of oil fuel are:

a. Low flash point. With fuel oil having a flash point not less than 150 degrees F. men of intelligence and common sense can handle oil as safely as coal.

b. Restrictions as to the location of storage tanks. Insurance companies and municipal authorities usually require oil fuel to be stored in underground tanks located not less than 30 feet from the nearest building.

c. Possibility of increased cost of boiler repairs when scale-forming waters are used, owing to the intense heat developed in the boiler furnace.

"The requirements for the perfect combustion of liquid fuel are as follows: reduction to a fine spray or complete atomization; bringing it into contact with the proper amount of air; mixture of oil spray and air burned in a furnace of a refractory material with room enough to complete combustion before the gases come in contact with the boiler-heating surfaces. The first condition is fulfilled by selecting a proper burner, and the remaining conditions can generally be obtained by making slight changes in, or additions to, the existing furnaces.

"The question whether to use steam or air for atomizing the oil seems generally to have been decided in favor of steam, as experimental results show that it takes about the same amount of steam to operate the air compressor as it does to atomize the oil at the burner, and the additional investment and complication involved with greater possibility of interrupted service is avoided. It is also easy to see that a flat fan-shaped flame presents a larger surface for heat radiation and uniform distribution of gases than any other shaped flame, and at the same time requires a minimum number of burners per boiler.

"Heating of the oil is an aid to economical combustion, and should take place as near the furnace as possible and be carried as high as safety permits, but not so high as to cause the oil to decompose and carbon to be deposited in the supply pipes. If preliminary heating is limited to the temperature of the flash point of the oil used, there can be no trouble from the above-mentioned causes.

"One of the most important questions in the combustion of liquid fuel is the regulation of the air supply in such a way

as to obtain perfect combustion before the gases come in contact with the heating surfaces of the boiler. This can be done with an automatic damper regulator, although its adjustment is rather difficult. It is therefore usually accomplished by hand regulation of the damper when considerable variations in the load take place. This is supplemented by changing the position of the ashpit doors, which are kept partly closed until a slight tendency to make smoke is noticed in the furnace, when they are opened until this tendency disappears; or, better, by using an Orsat or continuous CO_2 gas analyzer to determine the position of damper and ashpit doors which gives most complete combustion under certain recurring conditions."

Oil burners may be divided into two general classes, according to whether the oil and atomizing agent meet inside or outside the burner. On another basis of classification, five general types of burners may be recognized:

a. Drooling, in which the oil oozes out on the steam or air jet.

b. Atomizing, in which the oil is swept from the orifice by steam or air jet.

c. Chamber, in which oil mingles with steam or air in the body of the burner, and the mixture issuing from the nozzle is broken into minute particles by the expansion of the steam.

d. Injector, similar in principle to the boiler-feeding injector.

e. Mechanical spraying, effected by mechanical means without the use of atomizing agents.

"The important features which should be embodied in all burners are: ease of installment; construction that will allow quick inspection; easy removal of all foreign material which may clog the burner at any point; and rapid and cheap renewal of any parts subject to wear. In spite of the various principles involved in burner construction, the success of an oil-fuel installation depends not so much on the type of atomizer or burner used as on the method of its installation and the intelligence with which it is operated.

"To conform with the underwriters' requirements, storage

tanks above the surface of the ground should be placed at least 200 feet from inflammable property, and the top of the tanks should be located below the level of the lowest pipe used in connection with the apparatus. When the tanks are located underground they should be outside the building, at least 2 feet below the surface and 30 feet from any building, with the top of the tanks below the lowest pipe in the building used in connection with the apparatus. In small and medium-sized installations, steel tanks coated with tar, having a capacity of 8,500 to 15,000 gallons each, or 200 to 370 barrels of 42 gallons, are generally used for storage. In larger installations, reinforced-concrete tanks, generally rectangular in shape, are used. These are usually made with a partition in the center, so that any sediment or thick material may be periodically cleaned out without interfering with the continuous supply of fuel. The capacity of the storage tanks may vary from a supply sufficient for two weeks, when the oil is near at hand, and more may be obtained on one day's notice, to a supply sufficient for two or three months when the source of supply is at a considerable distance and delivery is in large quantities at irregular intervals.

" Storage tanks should be fitted with vent pipes, indicators showing level of oil in tanks, filling pipes, arrangements for freeing tanks from water, suction pipes, return or overflow pipes, steam pipes for filling space in tanks above oil with steam in case of fire, and suitable manholes for cleaning-out purposes. A suitable strainer should be installed on the suction line between the storage tanks and the oil-pressure pumps. The suction line should slope so that it will drain all oil back to the storage tanks when the pump is stopped and a vent opened.

" Duplicate oil-pressure pumps should be installed with pump governors, and all piping in connection with these pumps should be cross-connected in such a manner that a change can be made from one to the other and repairs made to either without interrupting the service. A suitable oil heater should be installed, so that the exhaust steam from the oil pumps

can be utilized to heat the oil before it reaches the burners. A suitable relief valve should be installed on the discharge line between the pumps and the burners set at a definite maximum oil pressure. An oil meter should also be installed in the discharge line to check the storage-tank indicator readings. All oil piping should be installed so that it can be drained back to the storage tanks by gravity in case of necessity.

" Provision should be made for removing any condensation from the steam lines to the burners. Automatic regulating devices should be installed to vary the pressure of both oil and steam to the burners in accordance with the demand for steam on the boilers, thus keeping a uniform steam pressure with a variable load, relieving the fireman of constant adjustment of burner valves and enabling him to take care of a much larger capacity of boilers than he otherwise could.

" In case a plant is operated only 10 hours per day, no steam being required for the rest of the 24 hours, it is necessary to install a small auxiliary boiler for the purpose of providing steam to atomize the oil while firing up the main boilers. In case of Heine or horizontal return-tubular boilers, the burners should be placed at the front, firing towards the bridge wall.

" It is sometimes an advantage to be able to change quickly from oil to coal and from coal to oil. This arrangement can generally be provided for, although in some cases, on account of a lack of sufficient combustion-chamber space, a more efficient furnace may be installed by making the change back to coal a somewhat longer process, requiring the insertion of bearer bars and grate bars, which would be left in place in the arrangement of the furnace first referred to."—"The Engineering Magazine."

SYSTEMATIC VERSUS SCIENTIFIC MANAGEMENT.

By E. C. Peck.

It is hardly possible at the present time to pick up a trade journal or magazine without seeing something about " scientific management." It seems to be a craze for everyone who

has ever done anything along this line to rush to the front with it, seemingly for fear that unless he gets it before the public, the two or three most prominent exponents of "scientific management" will absorb all the future credit for what seems to be a new era in industrial management.

It is not my intention to argue against a movement towards great efficiency. I believe in it thoroughly, but I am afraid that it will be much overdone. Attempts will be made to follow fixed laws without the keen discrimination necessary, and disappointments will be sure to follow.

According to the "Century Dictionary," "scientific management" as applied to manufacturing would be a management that had acquired accurate and systematic knowledge of the principles by observation and deduction. This seems to apply to the so-called "scientific management" perfectly, and I have no fault to find if we leave out the word "accurate." On this word the success or failure of the experiment may hinge.

From the layman's point of view, how are we going to know when we have acquired the accurate principles, and if we lay out a system accordingly and inaugurate it, what will happen to it if we discover that the acquired principles are not accurate? The decision as to the accuracy of the acquired principles will rest with the man we have hired as the "scientific management" expert, and the success of the venture will depend entirely upon his ability. He would have to be given full power, and large sums of money would be spent before the results were known. If he does not turn out to be the right man, it will not take many experiments of this kind to make owners thinks there is nothing in it.

The difficulty of obtaining an A1 man for any special position, and the number of candidates to be tried out, is well known, and it would be greater in the case of a scientific manager, because he is a comparatively new factor, and accurate knowledge as to his ability is hard to obtain. The importance and difficulty of getting the right man are clearly cited by one of the foremost exponents of "scientific management" in his paper on "Shop Management." He says: "The first

step after deciding on the type of organization should be the selection of a competent man to take charge of the introduction of the new system, and the manager should think himself fortunate if he can get such a man at any price."

This statement is so strong that it implies that the success of his system depends upon the ability of the man introducing it. There are a number of men in different parts of the country who are thoroughly capable of installing and carrying out "scientific management," and these men will make a success of it; but there will be a hundred who have had only a smattering of training along this line and who are not so capable. These are the ones to look out for, because they only think they know, and a great deal of money will be spent and many a shop turned upside down before one realizes that one has the wrong man.

Several of the most widely known exponents of "scientific management" state specifically that there is just one best way for every man to do a given piece of work. I do not agree with this except as applied to the most primitive work. There is a best way for a man to do a piece of work, but this way may not be the best for another man. No two people think and act alike, and the best set of movements for one man may be entirely wrong for another owing to his particular make-up. At work requiring skill a man who is speedy and naturally deft with his hands would have a different best way from the man who is less skilful and less speedy but stronger. I wonder how many would actually be competent to decide which is the one best way to play baseball, and what kind of a game it would be after the players had been instructed in this way and tried to use it. No doubt every barber's shop in the country could furnish one or more experts who could tell how it should be done, and the game would be benefitted just about as much as some industrial plants are by installing "scientific management."

From the foregoing it might be inferred that I am against "scientific management," and that I am not in favor of the

general movement towards greater efficiency. To prevent this article giving the reader the wrong impression, I want to state positively that I am in favor of any system which will produce more and better work for less final cost, provided the workman receives a percentage for his increased effort and skill. I am also in favor of collecting and keeping the necessary records for conducting the business in a systematic manner, but no more. Collecting unnecessary data costs money, and is of about as much use as tail feathers would be on a pig. Systematic management would be a better name for the particular brand that I favor, because if a business is systematically reorganized from top to bottom by a competent man, the leaks and weaknesses will be discovered. It will also be found where new blood is needed, and then the best attainable should be got.

An industry with a first-class man in charge of the manufacturing and working piece-work will not be benefitted much be "scientific management," because if the man is first-class he will systematize and organize everything under him, and he will have actual knowledge of the details of all the work and know whether or not his costs are right. He will also have the necessary records to do this with, if he has to sit up at nights to get them. He will be, in fact, a systematic manager, and a scientific manager according to some, without the planning department. He is his own planning department, and having *accurate knowledge* of the details of the work will only need clerks to tabulate it for him. He will not be fooled by the many excuses followed by the sharp ones to get a high rate, because the men soon know how much the boss can be fooled. He will not insist on every man doing a piece of work the exact same way, even his way, if he can produce results another way.

In one small shop with which I am familiar, an expert (?) has succeeded in saving £190 per year over previous methods, but the collection of the enormous amount of data necessary for him to do this cost £200 for the same period, and as every

slight change in the article manufactured makes most of these data obsolete, no reduction of this £200 is in sight. Adding the salary of the expert, this makes "scientific management" in that shop rather costly.

A man who thoroughly understood his business would have figured out the saving and compared it with the cost of collecting the data before going ahead. He should have seen that there was no saving, and then either reported this finding or attacked the problem from a different angle.

Another expert told a certain large concern, after spending several days in its plant, that its drilling was costing ten times what it ought to, and being a very fluent talker he was employed. He went around the shop and picked out the best men and induced them to drill a number of different size holes for him in the quickest possible time. He plotted these results, and according to the rules laid down by the different writers, he made an operation sheet with prices for the drilling. In his estimation he had accurate and systematic knowledge of the job on hand, and all that remained was to get the management to stand behind him and the results would be forthcoming. Some of the results were: a hairbreadth escape from a good healthy strike; loss of a number of good men; a barrel of burned-up drills; another of broken ones; a carload of scrap castings; and a state of affairs in general that made the owner "hit the ceiling" every time anything about "scientific management" was mentioned.

The reason for this failure was the lack of judgment and ability of the expert. He should have known that hard, dirty castings could not be drilled at the same rate as soft, clean ones, and that worn-out drill presses with a great deal of spring in them would break drills if pushed too hard. If he insisted on drilling at this rate, he should have seen that his working conditions corresponded with his test conditions, as to both material and machines. He should have taken the human factor into account or instituted a system of inspection and routine so accurate as to be able to ignore this element.

A man who understood his business afterwards put this shop in good order, and succeeded in doing the drilling for about one-fourth of what they were originally paying. He systematized the work, organized the inspection of material, and put it on a straight piece-work basis. I am afraid he would not be called by some authorities a "scientific manager," but he produced results at a very low cost, and when I visited this place I formed the opinion that it would be a long time before any expert would be able to lower the cost in this plant.

Another well-known concern with an enviable reputation for good work was built up and managed by two men; one in charge of the business end, the other of the entire manufacturing. The business started in a small way, and, owing to the energy and ability of the two men, grew until they employed about 400 men. The business was profitable and healthy, but the two men running it were sadly overworked, and needed each a good assistant to carry part of the load. The stockholders decided that what they needed was "scientific management" that they had outgrown their system, and that the two men who had built up the business did not know what modern organization was, but they might handle the new organization after they were properly trained.

After the scientific-management expert got the place organized (?), the man who formerly handled the business end was made general manager with the office of secretary and treasurer, and given as assistants an office manager, chief engineer, and chief draughtsman. The man who looked after the entire manufacturing end was made superintendent, and given as assistants an assistant superintendent, master mechanic, and production expert. It is hard to believe that stockholders could be talked into this large increase in the overhead against the advice of two such capable men, but they were firm in their opinion that they were behind the times.

The red tape under the new system handicapped the heads of the business, and in turn everyone down the line, to such an extent that orders could not be got out, mistakes of costly

nature occurred, traceable to errors in the engineering department or to improper relations between this department and the factory. New ways of doing things raised the cost in place of cheapening it. This was partly due to the friction in the organization and too many bosses; it took more time to correct errors than it formerly did to do the work. This company struggled along with this state of affairs for nearly two years, and is at the present time in the hands of a receiver.

Most of the writers on "scientific management" fail to place the proper value on the human factor. In my estimation it is of the utmost importance, and I believe when the end is reached it will be found that the saving effected will be inversely proportional to the skill required to do the work.

Most of the examples of large reductions in cost are those which require little or no skill and no brains at all. It seems perfectly logical to state that the more brains a man uses and the more skilful he is, the harder it is to improve on his methods. This has been my experience, and it is not at all uncommon to find skilful men producing first-class work in rapid time by almost diametrically opposite methods. How many of the experts are qualified to say which method is the right one, and would the man using the other method be let go if he could not maintain the required pace when forced to work by another method than the one at which he can produce results?

Again, some men are so skilful that they would make a poor method successful, and some are unskilful enough to make a failure of a good method. The man who can discriminate in this case will have to have no small amount of judgment and ability, and while I admit there are some who are qualified in this respect, there is going to be an epidemic of experts who will make enough failures to discredit the system.

My principal objection to "scientific management" as laid down by several of the best known writers is that it tends to destroy the ambition of mechanics, because they are not allowed to work and think for themselves, but must follow a blueprint. It is well known that really first-class mechanics

will usually find quicker and better means for doing the work than any imported expert, and this skill ought not to be hampered.

Twenty years ago apprentices were taught to be all-round mechanics. When they were given good work to do, they were told that Sam Jones did it the last time in nine hours, and the work was O. K. The apprentice's ambition was to scheme to do it in less time, because Sam Jones' ability was a well-known standard in that locality. He looked forward to the day when his work was to be held up to someone else following him up the ladder. His ambition was to be the best all-round machinist in the town, knowing that when he had that reputation he could command a high salary, and have a standing of importance in the community.

In most shops today apprentices are made into specialists, and there is a scarcity of all-round men. The majority of the good shop managers I am acquainted with were once skilled toolmakers, and when a good mechanic has learned to think he usually makes good. Training the rank and file as specialists for manufacturing is the correct idea, but let us have all the first-class toolmakers we can educate.

If we adopt systems which take away the ambition and initiative of the future skilful men, we will find ourselves without the very ability and skill which will be needed at the productive head of any systematized industry.

The prime requisites for a systematic producer are ability, judgment, and "stick-to-itiveness," and he can hardly be a "top-notcher" unless he has had enough practical training to make him entirely familiar with all the details. If none of this kind of men is trained, and we are forced to put either blueprint-trained men or the best of the automatons in charge of our production in the future, we can expect but little advancement. The United States is ahead of the world in mechanical manufacturing, and it is due principally to the efforts of good mechanics who have trained themselves to be good thinkers as well. We want greater efficiency all along the

line—managers, engineers, and workmen—but we don't want any kind of system which handicaps originality, thought and skill in the workman, engineer, or manager. We should strive to make more good mechanics, and induce them to study and think, so that when needed they can fill responsible positions.—"Iron Age."

SHIPS.

THE AUSTRALIAN NAVY.

The flagship of the Australian Navy, appropriately named the *Australia,* was launched on October 25th, from the Clydebank Shipbuilding Yard of Messrs. John Brown & Co., Limited. The occasion was quite justifiably celebrated as a great Colonial event, and Sir George Reid, the High Commissioner for the Commonwealth, with many Colonial and Admiralty officials, attended, the honors of the day being performed by Lady Reid, who is an Australian, although her husband is a Scotchman. The ship, with three second-class cruisers of 25 knots speed, six destroyers and three submarine boats, will form one of three units of a Pacific squadron, the other units, of corresponding composition, being provided by New Zealand and the home country, the latter unit to be identified with India. The Australian and New Zealand ships, designed by Sir Philip Watts, K.C.B., are being built under Admiralty supervision, but will be paid for by the Colonies, and will be utilized primarily for the defence of the island continents of the Pacific, but doubtless will conform to any scheme of strategy which may be deemed prudent when Imperial supremacy is challenged. In the policy pursued the Australians have adopted quite different procedure from that preferred in Canada, where up till the present there has been a preference for the construction of a fleet within the Dominion in order to develop the shipbuilding resources. Much can be adduced in favor of this idea; and even Australia aims at the foundation of shipbuilding, or at least ship repairing, resources, so that although two of the destroyers have been built in this country from designs by Professor Biles—one by the Fairfield Company and

the other by Messrs. Denny, of Dumbarton (see "Engineering," vol. xc., page 404)—the third has been sent in pieces to Australia, there to be put together, a process which will educate Colonial workers. The same procedure will be adopted with one of the smaller cruisers; the others are being built—the *Sydney* by the London and Glasgow Company, on the Clyde, and the *Melbourne* by Messrs. Cammell Laird & Co., at Birkenhead.

The cost of the fleet will not fall far short of four millions sterling, while the expenses of maintenance will be about 750,000*l.* per annum; and Lord Aberconway, the chairman of Messrs. John Brown & Co., Limited, in referring to the patriotic munificence of the Australian Colonies, found satisfaction in the fact that although the population of the Commonwealth was less than that of London, they were readily bearing this burden in addition to the normal calls of Government—a sacrifice which he felt would not be made by the Metropolis. He found two-fold reason for the organization of this fleet in the desire of the colonists to defend their territory against attack and to support the rest of the Empire's naval forces. This was in conformity with Imperial policy, which included—(1) the maintenance of a fleet unsurpassed, unequalled, unconquerable—more than sufficient to meet any combination of armed Powers that could reasonably be supposed to come together to attack our Imperial interests; and (2) the ensurance of absolute autonomy in every component part of the Empire. Sir George Reid went further, and sought to disarm foreign suspicion by pointing out that, although Australia was thousands of miles from any probable war center, the colonists recognized their obligations to the Empire, and were eager to maintain the flag of the mother-land. Indeed, throughout the speeches appropriate to the occasion there was as the dominant note the truism " to maintain peace, prepare for war," quoted by Lord Aberconway. Thus it was further recognized that this part of the Australian Navy was but a beginning of that large scheme sketched by Admiral Reginald Hender-

son, who was present, involving the creation within twenty-two years of a fleet of eight armored ships, ten protected cruisers, eighteen destroyers and twelve submarine boats, at a total first cost of 23 millions, a personnel of 15,000 men, and a maintenance charge of 1,226,000*l.* per annum.

Australia has begun well, because the flagship just launched will prove a most useful ship. Like the *New Zealand* and the *Indefatigable,* which latter will most likely form part of the Pacific Squadron, the *Australia* has a length over all of 590 feet, between perpendiculars of 555 feet and a beam of 81 feet 6 inches. The displacement tonnage is 18,800 tons at 26 feet 6 inches draught. These dimensions are less than those of the *Lion,* which was ordered earlier than the colonial ships, but was designed for other contingencies. The armament is equal almost to that of a *Dreadnought* battleship, there being eight 12-inch 50-caliber guns and sixteen 4-inch quick-firing guns, with two submerged torpedo tubes. The eight big guns can be fired on either broadside, and six ahead or astern. The midship guns are mounted on the beam, but *en echelon.* This is the principle adopted in the three first cruisers of the type and known as *Invincibles.* But a greater distance separates the guns in the longitudinal line in the newer vessel, and hence the length of the hull has been increased by 25 feet and the displacement by 1,550 tons. The Parsons turbines for driving four shafts, each with three-bladed propellers, have been increased in size and power to 44,000 shaft horsepower in order to ensure the same high speed, and although the vessel is of 25 knots legend speed, a rate of 26 to 27 knots is anticipated. Thus the Colonials may accept the view that their ships will be equal to the best that the money provided can secure.

The launch was in every way successful; that is only to be expected, from the experience and traditions of the Clydebank yard. Although none of the armor is in position, several of the boilers, which are of the Babcock & Wilcox type, are on board, and the vessel generally is in such a state of advancement that no difficulty should be experienced in completing it

within the contract time, which does not expire until a year hence. The tonnage at the time of the launch was about 7,000 tons. The vessel was cradled in the usual manner on 6-foot ways. This width of ways was used as a matter of convenience, and not from the necessities of the case, because, as is well known, ships can be, and are, successfully launched with pressures upon the ways up to 3 tons per square foot, whereas in this case the figure was less than half that amount. The declivity of the ways averaged $^{39}/_{64}$ inch per foot. The releasing gear was of the usual forged-steel pivoted-lever type, actuated by an electromagnet. The time occupied in launching from start to flotation was 72 seconds, quite a substantial proportion of which time was taken in moving the first foot, and in tripping the blocks left under the keels. Four drags of piled-up cables were used on each side of the ship, making up 480 tons, and these brought the ship to rest with the bow at 100 feet from the end of the ways. Subsequently the ship was towed into the fitting-out basin, there to be completed.—"Engineering."

CHINA.

The Chinese Navy.—According to the "Agence d'Extreme Orient," the previously published comprehensive Chinese naval program has been very materially reduced. The revised program comprises three maritime groups: firstly, a coast-defence; secondly, a section on the Yangtse River; and thirdly, some training ships. The first of these groups consists, at present, of four cruisers and some gun boats and torpedo boats, but to this group will be added four new cruisers, to be built abroad. The second group numbers twelve gun boats, and the third, two cruisers, ten gun boats, and some torpedo boats. Three small cruisers have recently been ordered in Germany, two in England, and one in the United States. At present there are several naval colleges, but it is proposed to reduce their number to two. After having completed their

education at home a number of young Chinese will be despatched to Europe and the United States for further studies. In addition to the above contracts China has ordered some torpedo boats and destroyers in Japan. Present events may, however, completely alter the plan.—"Engineering."

ENGLAND.

H. M. S. Medina, the Peninsular and Oriental liner, chartered for the conveyance of their Majesties the King and Queen to India for the Durbar, has been commissioned under the flag of Rear Admiral Sir Colin R. Keppel, with Captain A. E. M. Chatfield in command. The ship, which has been built by Messrs. Caird & Co., Limited, of Greenock, is 570 feet long, 62 feet 9 inches beam, 12,500 tons gross register, and about 20,000 tons displacement when loaded for service. There are seven decks, and cabin accommodation has been provided for about 450 first and 220 second-class passengers, and a crew of 160. There is thus adequate accommodation for the numerous suite of their Majesties as well as for the naval crew of 485 all told. The arrangements against untoward events are satisfactory, as there are ten watertight bulkheads extending to the spar deck, and a double bottom from stem to stern. The cuisine arrangements are exceptionally favorable, conforming to the highest standard of the P. and O. Company.

The machinery consists of two sets of quadruple-expansion engines, having cylinders of 30½ inches, 44 inches, 63 inches, and 89 inches in diameter, and a stroke of 54 inches. Steam is supplied by four double-ended and four single-ended boilers with a working pressure of 215 pounds on the square inch; the air is supplied to the thirty-six furnaces on the Howden forced-draft system. The condensers are of the Weir type, with a cooling surface of 7,800 square feet in each. The propellers are three-bladed, 18 feet in diameter, the pitch being between 22 feet and 25 feet, with 80 square feet of surface

to each propeller. There are two of Weir's "Dual" air-pumps, the other usual auxiliaries including refrigerating and electric generating machinery.

The engineers of the Peninsular and Oriental Company remain in charge of the machinery; but the firemen, etc., consist of Navy stokers, with the full complement of chief and petty officers, controlled by an engineer-lieutenant, R. N. The indicated horsepower is 12,000. During the recent progressive runs on the measured mile at about 12, 14, 16 and 18 knots, there was an entire absence of vibration, and the machinery worked up to full expectations. On these progressive-speed trials it was found that with 51 revolutions the mean speed was 10.45 knots; with 68 revolutions, 13.97 knots; with 75.6 revolutions, 15.29 knots; and with 85.4 revolutions, 16.87 knots; while at full power the speed was 18½ knots. As the vessel will steam at 16 knots or 16½ knots, it will be possible by increasing speed to ensure the correct times of arrival on the program irrespective of the weather.—"Engineering."

Steam Trials of H. M. S. Sandfly.—The torpedo-boat destroyer *Sandfly*, built for the British Navy by Messrs. Swan, Hunter & Wigham Richardson, Limited, Newcastle-on-Tyne, and fitted with her machinery by the Wallsend Slipway and Engineering Company, Limited, Wallsend-on-Tyne, completed on Monday, October 23, her official 8-hours' steam trials, when she attained a speed of 27.7 knots with the turbines running at a mean of 741 revolutions and developing 15,700 shaft horsepower. The designed speed was 27 knots. On her 24-hours' fuel-consumption trial on the preceding Wednesday the oil used was about 1 pound per shaft horsepower per hour. The *Sandfly* is 240 feet long, 25 feet 9 inches beam, and at 7 feet 10 inches draught displaces 780 tons. She is armed with two 4-inch quick-firing and two 12-pounder guns.

H. M. S. Archer, the first of five destroyers of special type under construction for the British Admiralty at the works of Messrs. Yarrow & Co., of Glasgow, was launched on Satur-

day, the 21st of October. The vessel is 240 feet long by 25 feet 7 inches beam, propelled by twin-screws driven by turbines of the Brown-Curtis type constructed by Messrs. Yarrow. Steam is supplied by three Yarrow water-tube boilers fired by oil fuel, and fitted with a special form of superheater designed by the firm.

FRANCE.

The torpedo destroyer Bouclier has been delivered at Cherbourg by her builders, the Chantiers Augustin Normand, of Havre. On the official speed trial of six hours, which took place on September 19th, the minimum speed at any time was 35.339 knots.

TURKEY.

Dreadnought for Turkey.—The order for a Turkish battleship has been officially confirmed by Vickers, Ltd., Barrow. She will have a displacement of about 23,000 tons, and will embrace many improvements on the latest British super-*Dreadnought*. She will have a speed of 21 knots, and will be fitted with Parsons turbines. Her ten 14-inch guns will place her in advance of any other ship yet built, and her secondary armament will consist of sixteen guns, with muzzle energy equal to that possessed by any super-*Dreadnought*. A sister ship has been ordered from Armstrong's.

OBITUARY.

HOLLAND A. STEVENSON.

Commodore Holland N. Stevenson was born in Cambridge, N. Y., on September 23, 1844, and died at San Francisco, Cal., on October 3, 1911.

A graduate of Van Ransselaer Polytechnic Institute, with the degree of Civil Engineer, he entered the Naval Academy in 1866, for the post graduate course in Marine Engineering. In 1868 Mr. Stevenson was warranted Third Assistant Engineer. In June, 1869, he was commissioned a Second Assistant Engineer; in December, 1874, a Passed Assistant, and in December, 1892, a Chief Engineer. By Act of Congress March 3, 1899, Chief Engineer Stevenson was transferred to the line of the Navy with the rank of Captain, and on June 30, 1905, he was retired upon his own application, with the rank of Commodore.

His first duty was on board the sloop-of-war *Dacotah,* in the South Pacific, from which vessel he was transferred to the *Saranac,* and in 1871 he was ordered to the Bureau of Steam Engineering to work on the designs for the compound engines of the *Swatara* class. He subsequently served in the *Swatara,* in the coast-survey steamer *Gedney,* as Inspector of Machinery at the Morgan Iron Works, on board the flagship *Trenton* in the Mediterranean, on the U. S. S. *Wyoming,* the coast-survey ship *Patterson,* as Inspecting Engineer at Chester, on board the U. S. S. *Alliance,* at the Newport Training Station, and as Inspector of Machinery at the Bath Iron Works. During the Spanish-American War he was Chief Engineer of the Monitor *Monterey,* from which duty he became Inspector of Machinery at the Union Iron Works. This was his last active duty.

Commodore Stevenson was an engineer skilled in all the branches of his profession, and a genial, even-tempered man of untiring energy. He had the rare faculty of commanding the high respect of his superiors while retaining the love of his subordinates. G. W. B.

WILLIAM H. ALLDERDICE.

Commander William H. Allderdice was born in Wilmington, Del., on December 15, 1859, and died at New London, Conn., October 3, 1911. He was appointed a Cadet Engineer at the Naval Academy on September 14, 1876, after competitive examination. He was graduated in 1880 and ordered to the *Alliance*.

In 1884 Mr. Allderdice was ordered as Professor of Mechanical Engineering at the Washington University, Missouri, on which duty he remained three years. He subsequently served on the U. S. S. *Lancaster*, at the Naval Academy as instructor in Engineering, at the Office of Naval Intelligence and on the U. S. S. *Bennington*. During the Spanish-American War, he was Chief Engineer of the *Newport*, after which he served on board the *Yorktown*, as Inspector of Engineering Material for the Middle Western District, with offices at Barberton, Ohio, as Inspector of Machinery at Newport News, Va., and as Inspector of Engineering Material at the works of the American Steel Casting Company, at Thurlow, Pa.

He attained the rank of Assistant Engineer in 1882, and of Passed Assistant in 1893. By the operation of the personnel bill he was transferred to the line of the Navy as a Lieutenant in 1899. He was promoted to Lieutenant Commander in 1902. On June 30, 1905, he was retired with the rank of Commander at his own request.

Commander Allderdice was possessed of a brilliant mind which manifested itself in a tendency toward literature without any sacrifice to his ability as an engineer. Though of a reticent disposition, he was companionable and very popular with his associates.

BOOKS RECEIVED.

EXPERIMENTAL ENGINEERING. By U. T. HOLMES, Commander, U. S. Navy. 301 pages, 152 illustrations. United States Naval Institute, Annapolis, Maryland. $2.50 net.

Contains concise and accurate descriptions of the methods and apparatus of experimental engineering by an author who is particularly well qualified for the work by training and by ability. As an advanced text-book or as a reference book, it will be found of great value to all who are interested in marine engineering, and the scope of the book is such that it will be of considerable use to those connected with other branches of engineering.

Much of the information contained in this book is not readily available elsewhere.

The subjects treated are: Engineering calculations—Reports—Instruments for computing experimental data—Instruments for recording experimental data—Thermodynamics—Entropy—Measurement of the quality of steam—Measurement of the rate of flow of water—Measurement of the rate of flow of air and steam—Measurement of power—Dynamometers—Torsion meters—Testing of materials—Engine lubrication—Testing of lubricants—The selection and testing of fuel—Fuel oil—Flue gas analyses—Time-firing devices.

J. H., JR.

SHIPYARD PRACTICE AS APPLIED TO WARSHIP CONSTRUCTION. BY N. J. MCDERMAID, Corps of Naval Constructors, Royal Navy. Longmans, Green & Co., New York. 328 pages. $4.00 net.

The book, as its title implies, deals with the methods and practice of building warships in British Yards, mostly Royal

Dockyards, and is compiled largely from lectures delivered by the Author to Cadets of Naval Construction at The Royal Naval College, Davenport. It includes chapters on the preparation for building, methods of laying off and erecting shell plating, decks, transverse and longitudinal framing, stem, stem framing and struts and the other essential structural parts of the hull, and touches also on rudders and steering gears, foundations for main and auxiliary machinery. Pages 82 to 88 describe in some detail the methods employed in framing and erecting barbettes.

A special chapter is devoted to the practical arrangements for launching and docking, and in the appendix a special treatment is given to the question of fore poppet arrangement in launching for heavy ships. The calculations for launching, the practical performance of the inclining experiment, and the question of circle-turning trials, items of prime interest to the constructor, are briefly but clearly explained. The subjects of pumping, drainage and flooding, together with fresh-water systems, are described at some length, as are also ventilation and the provisions for natural light. Coaling arrangements and anchor and cable arrangements have considerable space devoted to them, and the methods of developing the armor and preparing the molds for the same are described. Several of the important geometrical operations in ship building, such as laying off a longitudinal, determining the intersection of hawse pipes with ship's side, and the development of shaft bossing are discussed in a simple and direct manner. A special division is devoted to the construction of small boats.

The book, being for a special purpose, is, of course, based on British practice and deals with construction from the warship point of view rather than the merchant service, but presents a modern and very complete exposition of the methods in that very excellent service. For its scope and the subjects of which it treats, it is one of the best books now published in English .

R. H. M. R.

THE ELEMENTS OF THE MECHANICS OF MATERIALS AND OF POWER TRANSMISSION. By WILLIAM R. KING, U. S. N. (Retired), PRINCIPAL BALTIMORE POLYTECHNIC INSTITUTE. JOHN WILEY & SONS, New York. CHAPMAN & HALL, LIMITED, London. $2.50 (10/6) net.

This book is the outcome of several years of practical experience on the part of the author in teaching engineering students. It is in two parts, as indicated in the title. The first part takes up the mechanics of the strength of materials and treats the subject mathematically, using elementary calculus. Chapters on the strength of beams, columns and shafting, and on graphic statics of structures, follow. Also a chapter each on the materials of engineering and on testing materials.

Part II, relating to power transmission, is short, but covers the mechanics of transmission by belts and by toothed gearing. Numerous problems on these subjects are given.

Though intended primarily for use in technical schools and colleges this book will be found of value to any student possessing an elementary knowledge of calculus. It is well adapted to the needs of the student who is self taught.

ASSOCIATION NOTES.

In accordance with its By-Laws a meeting of the Society was held at the Navy Department, Washington, D. C., on Tuesday, October 3, 1911, for the purpose of making nominations for offices for the year 1912. Following are the nominations made:

For *President*, Captain Robert S. Griffin, U. S. Navy.

For *Secretary-Treasurer*, Lieutenant Commander John Halligan, Jr., U. S. Navy.

For *Members of Council:*

Engineer-in-Chief H. I. Cone, U. S. Navy.
Engineer-in-Chief C. A. McAllister, U. S. R. C. S.
Captain Emil Theiss, U. S. Navy.
Captain W. Strother Smith, U. S. Navy.
Lieutenant Commander E. L. Bennett, U. S. Navy.
Lieutenant N. H. Wright, U. S. Navy.

Ballots have been sent to all members. The votes will be counted at a meeting to be held at the Navy Department, Washington, D. C., on Friday, December 30, 1911.

At the meeting on October 3d it was voted that the Society hold a banquet, and the following committee was appointed by the President:

Engineer-in-Chief C. A. McAllister, U. S. R. C. S.
Captain W. Strother Smith, U. S. N.
Lieutenant Commander John Halligan, Jr., U. S. N.
Lieutenant N. H. Wright, U. S. N.

The Committee will endeavor to select a time for the banquet when the officers of the fleet will have an opportunity to be present, and also when Congress is in session.

Consequent upon his detachment from duty in Washington Commander U. T. Holmes, U. S. Navy, resigned as Secretary-Treasurer of the Society on October 3, 1911. The Council

elected Lieutenant Commander John Halligan, Jr., U. S. Navy, Secretary-Treasurer for the remainder of the year 1911. This election caused a vacancy in the Council membership, and Lieutenant Commander E. L. Bennett, U. S. Navy, was elected by the Council for the remainder of the year.

The following new members and associates have joined the Society since the publication of the last JOURNAL:

MEMBERS.

Allen, Francis C., Third Lieutenant of Engineers, U. S. R. C. S.
Coman, V. K., Lieutenant, U. S. Navy.
Daniels, M. R., Third Lieutenant of Engineers, U. S. R. C. S.
Davis, Lewis P., Lieutenant, U. S. Navy.
Decker, Walter B., Lieutenant, U. S. Navy.
Dutton, Benjamin, Jr., Lieutenant, U. S. Navy.
Gillis, H. A., 75 Home Life Building, Washington, D. C.
Gillmore, R. E., Ensign, U. S. Navy.
Jones, C. A., Ensign, U. S. Navy.
Libbey, M. A., Lieutenant, U. S. Navy.
Meyers, George J., Lieutenant, U. S. Navy.
Milner, Fred W., Lieutenant, U. S. Navy.
Oakley, O. H., Lieutenant, U. S. Navy.
Oberlin, E. G., Lieutenant, U. S. Navy.
Sterling, F. W., Lieutenant, U. S. Navy.
Thorn, B. C., Third Lieutenant of Engineers, U. S. R. C. S.
Woodward, K. C., 143 Longwood Avenue, Brookline, Mass.

ASSOCIATES.

Bedford, Russell B., care of American Blower Co., 141 Broadway, New York City.
Donaldson, H. Beaumont, Vickers, Ltd., Peking, China.
Gilmour, James, The Craigs, Duntocher, Dumbartonshire, Scotland.
Lalor, James D., 1326 Chestnut Street, Philadelphia, Pa.
Reeder, F. E., Fulton Company, Knoxville, Tenn.
Rosenthal, James H., Managing Director, Babcock & Wilcox, Ltd., Oriel House, Farringdon Street, London, England.
Young, Philip M., 1224 Walnut Street, Philadelphia, Pa.